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THE MARITIME AND RURAL LIFE OF NORWAY

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Norway is known to all as one of the most picturesque of countries. A mountain fringe of ancient rocks, cut by deep depressions and half drowned in the waters of the North Atlantic, the first characteristic it offers to the traveler is the extraordinarily articulated coast, with a length of 17,000 kilometers where the distance in unbroken line is barely 3000, and the extraordinary number of isles and islets, 150,000 say the Norwegians. The isles and the tortuous channels that separate them from the mainland constitute the *skjærgaard*, the skerry guard. To the south and again in the extreme north the uplands of the interior stretch in broad plateaus, fjelds, ranging from 500 to 1500 meters in average height and terminating at the coast in abrupt cornices. In and northward from the center, in Romsdal, Lyngenfjord, and the Lofoten Islands the mountains, rising to about the same altitudes, present alpine forms. Both alpine mountains and plateaus are fragmented by deep fiords, narrow and winding, which penetrate to the heart of the massifs where the sea waters are imprisoned as it were between two walls. The Sognefjord, for instance, is 1244 meters (4081 feet) deep and penetrates 145 kilometers (90 miles) into the interior. Along the seacoast and up the fiords the precipitous walls of the fjelds and the Norwegian Alps are in places bordered at water level by a sort of bench, forming a series of little discontinuous coastal plains. Here live the farming and fishing folk of the fiords. To the southeast the country of the fjeld sinks, opening into broad valleys with forest-covered slopes; these valleys converge on Christiania, the capital of the country.

At sea level and in the lower regions the country is almost everywhere open to the tempering influence of the rains and mists of the Atlantic. At the same time, as it extends over 13 degrees of latitude—from 58° N. to 71° N.—there are pronounced differences of climate and vegetation between north and south. The south with its wheat fields and forests of oak and beech mixed with conifers pertains to central Europe; the north, with

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FIG. 1—Sketch map to show the Norwegian localities mentioned in the text. Scale 1:12,000,000. See also for the areas shown in the maps of population distribution, Figure 2.

FIG. 2—Reproduction on a reduced scale (1:1,900,000) of typical portions of the population distribution map of Norway by Alfred Söderlund discussed by Mark Jefferson in this number of the *Geographical Review* (pp. 651–652). The land is distinguished by the darker tint (yellow in the original): see also Figure 1. The small black dots represent each 100 people; the "spheres," towns of over 3000 people; the small circles, the seasonal population movement for the sea fisheries.

soil of frost-splintered stones, with mosses, lichens, willows, and dwarf birch, is an arctic land. In the intermediate region the great variety of transitional forms is rendered more pronounced by the seasonal prolongation of days and nights and the increasing obliquity of the sun's rays which makes of arctic Norway a country of marvelous play of light and shade. Everywhere abound the waters derived from the Atlantic vapors, in the form of snow fields and glaciers on the domed heights of the fjelds and in the depressions of the alpine crests; as cascades tumbling down the abrupt sides of the fiords; as lakes and glacial torrents in the maze of narrow valleys which open into the fiords of the Atlantic and Arctic Oceans or in the broader valleys converging in the southeast toward the Skagerrak.

The Norwegian People

The harsh and inclement soil of Norway supports a small enough population—only two and a half millions on 125,000 square miles. It is not surprising: here man has three enemies—barren rock, high altitude, northerly latitude. But the people are robust, remarkable alike for tenacity and patience and cohesiveness. These qualities have triumphed over natural obstacles: the Norwegians have succeeded in combining into a national body the small groups scattered over a vast area and separated from one another by ice, mountain, or sea. On the western coasts in the Middle Ages lived the hardy seamen and pirates, the Vikings, that carried terror to all the shores of Europe. On the plains of Trondhjem arose the confederations of *bönder;* and here in the eleventh century, under the chieftain known as Saint Olaf, the chief force of the country was concentrated. From Stavanger to Aalesund and from Trondhjem to Christiania the clans of the Vikings and the tribes of the *bönder* were united, and Norway came into existence—that is nearly nine centuries ago.

Her people, it is true, have known long periods of submergence. The fiord dwellers of the west were reduced to a state of economic bondage by the Germans of the Hanseatic League; for four centuries Norway was a political dependency of Denmark; in 1814, though she acquired autonomy, she was compelled to accept a dynastic union with Sweden. It was only in 1905 that the last bond was broken and Norway regained the absolute independence she had enjoyed in medieval times. Her people—farmers, sailors, artisans, animated by a truly democratic spirit—hold an honorable position in modern civilization. Yet the country has not renounced the old traditions; on the contrary she clings to the most ancient of them with singular persistence. Especially among the farming folk one sees an active attachment to the past associated with a characteristic individualism.

Along the Fiords and on the Fjeld

Let us follow the shores of the fiords on one of the little mail steamers that may be met with almost anywhere. Where the fiord walls sink to

FIG. 3

FIG. 4

FIG. 5

FIGS. 3, 4, and 5—Fishing villages of northern Norway. Figure 3, Bergsfjord, latitude 70° N., has about 200 inhabitants and electric light, telephone, and telegraph. Figure 4 is Kjöllefjord, east of North Cape. Figure 5 is Skærvöy, latitude 69° 50′ N. (Photographs by H. P. Ulich.)

a coastal bench one sees meadows, fields, and houses built of wood and often painted in brilliant colors and always standing alone. These are the *gaards*, the estates of the peasant proprietors. The *gaards* are never in groups: often on a strip of plain, quite unconnected with the rest of the world, will be seen a single *gaard*. At long intervals rise church and bell tower, equally isolated; and here before your eyes is the center of a rural

FIG. 6—Bakke, near Gudvangen, Nærøfjord.

community, *herred*, the political and social bond between the *gaards* separated from one another by rock walls and arms of the sea. In all Norway there are but 640 *herreder;* hence you may gauge the extensive area of these rural communities.

Two questions naturally arise: how do the inhabitants of the *gaards* gain a livelihood, and how do they communicate with their neighbors, the nearest of whom are often far distant?

Around the *gaards* are small fields, carefully tilled, growing a little wheat in the extreme south but chiefly rye, oats, barley, and potatoes, and for cattle fodder a crop of turnips. In many fiord valleys the chief cultivation is a mixed crop of barley and oats (*blandkorn*). On the warmer slopes of the south and especially in the more genial climate of Hardangerfjord, the sun-

niest part of Norway, cherries, apples, and pears flourish; farther north, as far as Trondhjem, gooseberries are an important crop.

Although such exploitation of the soil is a real triumph of ingenuity and patience, it does not suffice to support the population, small as it is. As one travels northwards vegetables, grains, and fruits dwindle in size, and their production is small. In Norway the area under food crops represents only a

FIG. 7—Sognefjord. (Photograph by H. P. Ulich.)

small fraction of the land, hardly a hundred-and-forty-fourth part; and it is impossible to increase this proportion. As a matter of fact the farmers of the fiords, like the fishermen, live largely on fish. For the most part, however, they do not make the catch themselves, for the waters of the fiords are not well stocked. Fish must be bought, and cattle serve as the medium of exchange. His cattle mean far more to the Norwegian farmer than his crops. The cultivated part of his farm (*indmark*) is of limited extent; in contrast his pasture (*udmark*) is practically limitless: it includes immense stretches of fjeld where the cattle are grazed in the summer. The fjeld is the Norwegian alp: it has its summer chalets, the *sæter*.

The life of the *sæter* lasts during the two or three months of summer in the great fjelds of the southern region (between Christiania, Bergen, and Trond-

hjem) from 200 to 600 meters in altitude. Then the fjeld is occupied by cattle grazing in complete liberty. At the end of the season descent is made to the *gaards* for the long and trying winter season, trying because the scant resources of hay and root crops do not always suffice the need, especially in the north. Should these resources fail recourse is had to fish offal, the herring of Romsdal or the cod of the Lofoten Islands. The cattle accommodate themselves very well to this kind of food—a strange thing in herbivorous animals.

On the fjelds of Nordland and in the extreme north the pastoral life of the Norwegian farmer and his cattle is of little moment. From the latitude of Trondhjem northward the country is largely occupied by the Lapps and their herds of reindeer. These curious nomadic people and curious arctic animals range from Norway through Sweden into Finland: Lapland with its indefinite limits stretching over the boreal zone of these three countries.

The Norwegian farmer of the *gaards*, in spite of the immense stretches of the *udmark* where he pastures his cattle, would seem to lead an isolated life—a fact reflected in a way in his taciturnity and reserve and also in his repugnance to any form of co-operation. Yet, isolated as he is, he is not a savage; and indeed the physical isolation is not so great as one might at first sight imagine. The lowland strips along the shores and narrow valleys sprinkled with *gaards* are often in communication by narrow open passes (*eide*) over the fjelds: of glacial origin, these passes are well adapted to the establishment of roads. Telephone wires run the length of the fiord and across the fjeld from *gaard* to *gaard* and even from *sæter* to *sæter*, and the fiord itself is a highway open to the possessor of a boat. During the year traveling schools go from farm to farm to give instruction to a people avid of learning. Physicians also make tours of their communes for the spread of hygienic knowledge; and the telephone and the telegraph make it possible to call the doctor in good season to the bedside of the patient even in the most distant *gaards*.

The great valleys and forests through the whole southeastern part of Norway where the valleys, roads, and railways converge toward the Christiania Fjord, Gudbrandsdal, Hallingdal, and the lake-filled valleys of Telemark, the physical isolation of the Norwegian peasants becomes less marked. The "*gaards*" approach one another and form groups; cultivable lands are more extensive and follow one after the other, no longer separated by masses of barren rock but by vast and magnificent forests that are among the most beautiful in Europe. These southeastern valleys are preëminently the domain of the peasant aristocracy, the *bönder*, which actually governs the country; their forests are one of the principal sources of wealth of all Norway.

The forests for the most part are masses of evergreen, Scotch fir and Norway spruce, the uniform tones of which are happily brightened here and there by the silvery flashes of the birch. They cover no less than 70,000 square kilometers, or more than a fifth of the total surface of the country. Although the forests belong to the state or to individual Norwegians and

form an essential element among the resources of the nation, the lumbermen are not all Norwegians. Quite often, especially in the immense forests along the Swedish frontier, they are of the Finnish race, descendants of Finnish immigrants of the seventeenth century. If we consider this in connection with the occupation by the Lapps of the great fjelds of the nørth, we may understand the truth expressed in the official account published on the occasion of the Paris Exposition of 1900 to the effect that "the Norwegians are a coast people and to a certain extent a valley people." Indeed they prefer not to live anywhere else.

FIG. 8

FIG. 9

FIGS. 8 and 9—Examples of the *stabbur*, barn granary, in Telemark.

There are those, however, who profit by the trade at the lumber-exporting wharfs (*ladesteder*), the chief of which are round Christiania—Skien, Fredrikstad, and particularly Drammen. Some 400,000 cubic meters of rough or half-finished lumber are exported annually, and also 350,000 cubic meters of pulp wood and cellulose. The wood industries are very prosperous as they are favored by the abundance of water power, and since the development of hydro-electricity sawmills and pulp works have multiplied greatly. Today exploitation of the forests is arousing from economic torpor the old province of Nordland between Trondhjem and Bodö. Its splendid forests have been little utilized up to the present. Exploitation, however, will come when the railway system, which now terminates a little to the north of Trondhjem, is extended to Bodö, well beyond the arctic circle.

SEA FISHERIES OF THE SKERRY GUARD

On the coasts of Norway there is no clearly defined line between farmer and fisherman. The farmer has his boat and fishes when he has the op-

FIG. 10

FIG. 11

FIG. 12

FIG. 10—Henningsvær, a fishery station in the Lofotens.
FIG. 11—Another view of Henningsvær.
FIG. 12—Hammerfest.

portunity; he catches salmon in the fiords and sets his herring nets at the entry of the narrow tidal channels. The fisherman tends the little fields about his "*gaard* even on the rocky islets, scant of soil and exposed to the high winds from the sea; invariably he has some pasture land and at least one or two cows. As the most productive fishing takes place in the winter, the fishermen find time to work on the land in spring and summer. But this combination of occupations is realized in full only as far north as the latitude of Trondhjem. Beyond that as one proceeds northward the land becomes hostile to all cultivation, and man looks for his support to the sea. Furthermore, it is in the subarctic and arctic zones that the fisheries are most fruitful. Eighty per cent of the entire catch of the Norwegian coast is taken north of Cape Stat.

The fisheries of the skerry guard are classed as daily and seasonal. The former furnish fresh fish daily to the markets of the coast towns. Bergen possesses the most famous and most interesting of these markets where from the fishponds of sea water constantly renewed the buyers can choose haddock, redfish, mackerel, turbots, conger eels, and also crustaceans (lobsters and prawns), which the waters of the continental shelf and the sounds yield in abundance. Every Norwegian port has its quays and fishing

basins where boats with and without decks rock on the waves and where the movement of coming and going, the discharge, sale, and despatch of fish testify to the importance of the industry. The coast towns, Stavanger, Bergen, Christiansund, Aalesund, Trondhjem, have each its fishery quarter and its fishermen, as do the towns of the Mediterranean, and are as rich in color and life as are they.

The seasonal fisheries from the south of Norway to the north of Trondhjem include chiefly those of the sprat, a sort of large sardine, and the herring. The sprat fishery takes place in winter, that of the herring in summer. Nets of different types are used for both. In the case of the herring extraordinary catches are sometimes made at the entrance of the tidal channels, which constitute a kind of trap. The catch is in large part destined for export, and there are curing and canning establishments at many points of the coast, notably at Stavanger and Aalesund. Salted herring is the chief export.

Although the fishermen are no more predisposed to co-operation than the farmers, it has in some measure been forced on them by the nature of their calling and by desire to increase the yield of the fisheries. They have especially profited by the admirable work of the Norwegian oceanographers B. Helland Hansen, Michael Sars, and Johann Hjort on the physics and

FIG. 13

FIG. 14

FIG. 15

FIG. 13—Encampment of Lapps near Lyngen.
FIG. 14—Glaciers of Lyngenfjord.
FIG. 15—Glacier of Svartis.

biology of the sea. Equipment also has been modernized. For all kinds of fishing, use of motor boats has increased enormously in recent years: in 1914 there were only 209 such boats; at the end of 1922 they numbered 1503.

The Cod Fisheries of the Lofotens and Finmark

Of the seasonal fisheries much the most flourishing and important in general trade is the cod fishery of the waters of the Vestfjord to the south of the Lofotens and on the coast of Finmark.

At the foot of the snow-covered crests of the Lofotens are the wooden wharves of some forty fishing stations (*fiskever*), of which Svolvær is the chief. Hither at the end of winter, from February to March, assembles a flotilla of fishing boats and cargo boats, the former to make the catch, the latter to carry it away. At that season the cod shoal in the waters of Vestfjord and draw fishers from afar, from all the coasts and interior of Norway and even from Swedish Lapland. To the number of eleven or twelve thousand, not including the women and children, they establish themselves in the fishing stations, taking up their quarters in the *rorböder*, great wooden sheds. Thence they set out each morning, with motor boat, sailboat, or even rowboat to fish for cod all along the Vestfjord. Equipment is as varied as the boats—bottom nets, bottom lines, ordinary lines with sinkers.

The fish are prepared for exportation on the spot: this explains the presence of women and children. There are two types of preparation. Stockfish (*torfisk*) is made by removing the heads and entrails and drying the fish on wooden platforms. The preparation of *klipfisk*, which is held in greater esteem and has a higher market value, is somewhat more elaborate. The initial stage is the same as that of the stockfish; then the fish are salted in the shed and dried in the open air on the flat or slightly rounded rocks that form the shore of the Lofotens. Fish thus prepared are exported all over the world. The production of the fisheries of the Vestfjord for these two months is valued at an annual figure of from fifteen to twenty million gold francs.

As April approaches the cod begin to leave the waters of Vestfjord and appear in increasing numbers off the shores of Tromsö and Finmark whither they pursue a small fish, the capelin, then abundant in these waters and their chief prey. Now the fishing season of Finmark begins and is prosecuted with great profit up to July. Tromsö and Hammerfest are the chief stations for this industry.

Distant Fisheries and Ocean Trade

Although the resources of their own seas are so rich and so varied, they do not satisfy the Norwegian fishermen, who seek more distant fields and a larger prize. They have long found profit in the whaling industry, and to its perfecting they have made notable contributions. It was a Nor-

wegian, Svend Foyn of Tönsberg, that in 1868 invented the harpoon gun, today in use on all whaling vessels. Formerly the Norwegians exploited the Arctic seas as far as Spitsbergen, now recognized as a political dependency of Norway; but since the beginning of the century they have abandoned these regions, at least temporarily, for whales have here become scarce. Today it is off the coasts of equatorial Africa and in the southern Atlantic that the Norwegian whalers pursue their laborious but lucrative calling. Steamships of five hundred to six hundred tons outfitted at Tönsberg, Larvik, and Sandefjord in the environs of Christiania are generally employed in the industry.

Seal hunting and walrus hunting are still conducted in the waters of Iceland and Spitsbergen by means of motor boats of eighty to one hundred tons outfitted at various west coast ports, notably Aalesund, Tromsö, and Hammerfest.

A numerous and hardy marine, experience in the hunting and fishing of all kinds of sea animals, timber in abundance for the building of boats as well as for export—these are the chief elements whence has developed the great maritime commerce of Norway. In spite of the competition of other forms of industry it still remains the principal and most flourishing feature of the economic life of the country. Its vitality is proved by the way in which equipment has been modernized and the extent to which steel ships and motor power have increasingly replaced the old sailing ships. The mercantile marine has rapidly made good the losses sustained during the war—976,000 tons, more than that of any other nation except England. With its 2,630,000 tons, of which nine-tenths are under steam, Norwegian shipping holds third rank in Europe.

The great shipping towns are Christiania and Bergen. Christiania holds first rank for port movement, Bergen first for tonnage of vessels belonging to its outfitters. But the maritime activity of the country is not limited to these two towns; it is dispersed all along the coast from Christiania to Trondhjem. Every port has its share; all are active and flourishing.

The Future: Industry and Labor

By virtue of her products of forest and sea Norway has long enjoyed a measure of industrial activity: lumber has been worked by water-driven sawmills; oil, codliver oil, and guano have been extracted from fish and exported from several places, especially Svolvær and Bergen. But it is hydro-electric power that has given rise to the present industrial development of the country. Though raw materials are not abundant—there is only a little iron and copper—the resources of hydro-electric energy are so great and so easily put to service that several large industrial plants have been established. Falls already harnessed give 1,630,000 horse power, and potential power is reckoned at 12,000,000 horse power. The chief plants, those at Notodden, at Rjukan, and at Odde in southern Norway, are devoted to

the production of industrial nitrogen, calcium carbide, and nitrogenous fertilizers.

This large-scale industry has created in a country of fishermen, sailors, and farmers an artisan class whose numbers are rapidly growing and growing especially at the expense of maritime industry. Here the numbers are diminishing especially in the ruder branches, such as the winter fisheries. The farmer class does not diminish. Fifteen years ago maritime industry occupied 158,000 workers: it now counts only 109,000 (against 650,000 on the land). The figures indicate a movement of social evolution destined without doubt to change in some measure the physiognomy of picturesque old Norway.

AVALANCHES

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At the end of December, 1923, the occurrence of a great number of avalanches brought much suffering and inconvenience to the high valleys of the French Alps. In Oisans and Briançonnais many roads and railways were cut. In Upper Tarentaise an entire village was engulfed, and several persons and all the cattle were lost.[1] In Upper Maurienne the highest villages were cut off from all outside communication for five days; they had no post, no bread, no telephone, no electricity. On the roads and in the châlets isolated men were overwhelmed. The international route from France to Italy by Maurienne and the Mt. Cenis tunnel was cut and also the lines to Chamonix and Bourg St. Maurice. The total losses in the French Alps alone in the last week of 1923 may be put at some 14 human lives and nearly a million francs.

Now these catastrophes are in no way exceptional. They occur many times during the winter in the alpine regions. Each mountain massif has its ravines down which avalanches descend every year. It is only the size of the avalanches that varies; in normal years they are generally limited and do little damage; exceptionally one or more assume catastrophic dimensions. In the same winter in the same valley there may occur simultaneously both small and large avalanches. The frequency and periodicity of avalanches and the permanent menace which they present in the mountains are sufficient reason why this phenomenon has been well studied in the mountainous regions of Europe.

Studies on Avalanches

On the subject of avalanches there are no less than 50 recent works worthy of note; 17 are French, 11 Swiss, 11 German or Austrian, 8 Italian, 3 Scottish. With the exception of the fundamental works of Coaz and Heim, both Swiss, they date back less than 20 years. The greatest part of this literature is due to alpinists and ski runners, the people who have the greatest reason to fear avalanches and who have the best opportunities for direct observation.[2] Then come the studies made in Switzerland and France

[1] F. Gex: Les avalanches de fin décembre 1923 en Savoie, *Rev. de Géogr. Alpine*, Vol. 12, 1924, pp. 129–155.

[2] W. W. Naismith: Snowcraft in Scotland, *Scottish Mountaineering Club Journ.*, Vol. 2, 1892–93, pp. 137–167.

F. W. Sprecher: Grundlawinenstudien, *Jahrbuch Schweizer Alpenclub*, Vol. 35, 1899, pp. 268–292; Vol. 37, 1901, pp. 219–243.

Max Madlener: Über Schneelawinengefahr, *Deutsche Alpenzeitung*, Vol. 3, 1903–04, pp. 169–173.

Josef Müller and A. von Radio-Radiis: Gefahren des Schneeschuhlaufes in den Hochalpen, *Mitt. Deutsch. und Oest. Alpenvereins*, Vol. 30, 1904, pp. 8–9 and 17–18.

Wödl: Die Lawinengefahr bei winterlichen Hochtouren, *Oest. Alpenzeitung*, Vol. 26, 1904, pp. 73–82.

by members of the Forest Service. The work of Dr. Coaz, former director of the Swiss Service of Waters and Forests[3] still remains at the head of this category; but the French foresters have lately made some notable additions to the literature of the subject.[4]

More recently geographers and glaciologists have been responsible for valuable contributions.[5] To these three distinct categories of scientific studies on avalanches must be added numerous descriptive and popular articles among which much useful information is to be found.[6] It should, however, be observed that several of the first category and many of the other categories derive from a common source; they are descendants of

H. von Ficker: Winterschnee und Lawinenbildung, *Oest. Alpenzeitung.*, Vol. 27, 1905, pp. 13–20.

W. Paulcke: Manuel de ski, traduit de la troisième édition allemande par F. Achard, Paris and Nancy, 1905.

Harold Raeburn: Scottish Snow, *Scottish Mountaineering Club Journ.*, Vol. 8, 1905, pp. 285–298.

Emil Zsigmondy and W. Paulcke: Die Gefahren der Alpen, 4th edit., Innsbruck, 1908 (the chapter on avalanches is by Dr. Paulcke and has been added to this edition).

Henry Hoek: On Snow Avalanches, *Alpine Journ.*, No. 175, Vol. 23, 1906–07, pp. 379–386.

Mathias Zdarsky: Die Skiaugen im Gebirge, *Der Schnee* (*Wochenschrift der Alpen-Skivereines*), Vienna, Vol. 2, Nos. 22, 24, 25, 26, 27, March 30 to May 4, 1907.

Henry Hoek and E. C. Richardson: Der Schi und seine sportliche Benützung (cover title, Der Schilauf), 3rd edit., Munich and Vienna, 1908 (French translation by Louis Arnaud, Le Ski, Grenoble, 1909).

Ernst Büss: Über die Lawinen, *Jahrbuch Schweizer Alpenclub*, Vol. 45, 1909–10, pp. 250–273.

F. W. Sprecher: Alpiner Skilauf und Lawinengefahr, *Ski* (*Jahrbuch des Schweiz-Skiverbandes*), Vol. 8, 1912, pp. 10–26.

Adolfo Hess: Le valanghe, *Riv. Mensile Club Alpino Italiano*, Vol. 35, 1916, pp. 302–317.

Fritz Rutgers: Die Lawinengefahr für Touristen, *Ratgeber für Bergsteiger*, Vol. 1, 1916, pp. 98–133, herausgegeben von der Sektion "Uto," Schweizer Alpenclub, Zürich.

Max Oechslin: Ein Beitrag zur Kenntnis der Lawinen, *Alpina: Mitt. Schweizer Alpenclub*, Vol. 31, 1923, pp. 303–312.

[3] J. Coaz: Die Lawinen der Schweizeralpen, 2nd edit., Berne, 1881.

Idem, Die Lawinenschaden im Schweizerischen Hochgebirge im Winter und Frühjahr 1887–1888, Berne, 1889.

Idem, Statistik und Verbau der Lawinen in den Schweizeralpen, Berne, 1910.

[4] V. Hulin: Les avalanches, *Ann. Soc. des Touristes du Dauphiné*, Grenoble, Vol. 37, 1911, pp. 235–266, and Vol. 38, 1912, pp. 205–229.

P. Mougin: Les avalanches en Savoie, forming pp. 175–322 of Études glaciologiques, Vol. 4, Direct. Gén. des Eaux et Forêts, Minist. de l'Agric., Paris, 1923 (the bibliography gives 7 earlier works of the author, published or unpublished, and those of his collaborators of the Conservation des Eaux et Forêts de Chambéry, summarized in this very important work. See also the account in *Rev. de Géogr. Alpine*, Vol. 11, 1923, pp. 800–805). I have to thank the Inspector General of Forests, M. P. Mougin, for the right to reproduce the photographs of M. V. Hulin who made the collection for the French forestry administration. I am equally grateful to M. Hulin, chief of forestry of Grenoble, for the willingness with which he has placed at my disposition his knowledge, data, and photographs. With M. J. Brocherel, cited below, to whom I am equally indebted, he is a specialist in photographing avalanches. All his views are taken in Dauphiné; those of M. Brocherel come for the most part from the Italian Alps.

[5] Albert Heim: Handbuch der Gletscherkunde, Stuttgart, 1885.

Vincenz Pollack: Über die Lawinen Oesterreichs und der Schweiz und deren Verbauungen, *Zeitschr. Oest. Ingenieur- und Architekten Vereins*, Vol. 43, 1891, pp. 18–39.

J. Brocherel: Le valanghe, *Emporium: Rivista Mensile Illustrata d'Arte, Letteratura, Scienze e Varietà*, Vol. 41, 1915, pp. 293–309.

E. Bénévent: La neige dans les Alpes Françaises, *Recueil des Trav. de l'Inst. de Géogr. Alpine*, Vol. 5, 1917, pp. 403–497.

F. Gex: Les avalanches du rebord subalpin de la Combe de Savoie, *La Géographie*, Vol. 39, 1923, pp. 36–52 and 165–179.

Idem: Les avalanches en Savoie durant l'hiver 1922–1923, *Rev. de Géogr. Alpine*, Vol. 11, 1923, pp. 487–511.

André Allix: Les avalanches de 1922–1923 en Dauphiné, *ibid.*, Vol. 11, 1923, pp. 513–527.

See also works cited later.

[6] J. G. Ebel: Anleitung, die Schweiz zu bereisen, 4 vols., Zürich, 1809.

Jules Michelet: La Montagne, 7th edit., Paris, 1868.

Charles Rabot: Pierres qui roulent, neiges qui tuent, *Lectures pour Tous: Rev. Universelle et Populaire Illustrée*, Vol. 6, 1904, pp. 505–513.

Mario Tedeschi: Le valanghe nell'Inverno, *La Sorgente*, Touring Club Italiano, Vol. 6, 1922, pp. 31–45 et al.

the work of Dr. Coaz. None can pass as definitive; the subject is too vast. The present work makes no attempt to be exhaustive. It simply aims to give an outline of the whole, especially intended for geogra-

FIG. 1—Glacier avalanche on the southern face of the Grandes Jorasses, French slope of Mont Blanc. (Photograph by J. Brocherel.)

phers. In the process some new observations will be presented, together with a plan for clarifying the vexed question of classification and a discussion of the only phase of the subject that has not received much attention—the prediction of avalanches.

Avalanches without Snow

A great variety of phenomena bear the name "avalanche" or an equivalent term,[7] *lavanches, laves, lavines, laui, lawinen, valanghe,* and yet fall outside the range of this study. They are accidents likely to occur at any season of the year and involving other material than snow. The fact that common speech has only a single word for these various occurrences is proof of their similarity at least as regards general appearance and human consequences; but physically and geographically they are entirely distinct phenomena. Earth slides are those which most nearly resemble snow slides. When a mass of earth begins to slide and still retains a certain cohesion it moves as a block or blocks without other apparent deformation than the change in level: this is the *foirage* (landslip) of the French authors and resembles the *planche* (board) of snow, the initial phase of the snowy avalanche. If the earth continues to slide a sufficient distance the mass breaks up, becomes pulverized, and then moves as a fluid substance; a phenomenon analogous to the course pursued by the ground avalanche. The terms "landslide" and "Bergstürz" are unfortunately common to the two cases.[8] Somewhat different but belonging to the same family is the rock flow, resembling in its movement, if abrupt a volcanic flow,[9] if slow a glacier. It has been well studied in America and Switzerland under the name of rock stream.[10] In both cases there is involved a mass of earth permeated with water and moving as a viscous fluid.

While lava flows, as their name indicates, belong to the same family, real avalanches of cinders or volcanic ash have also been studied, "dry avalanches," the characters of which are almost identical with those of snow avalanches.[11] Lastly all alpinists know that the cliffs of glaciers often give way in summer, producing "summer avalanches" or "glacier avalanches" (Figs. 1 and 2). Conditions of formation in this case are evidently entirely different from those of snow avalanches[12] and involve falls of ice rather than slides properly so termed. J. Brocherel has recently investigated an instance where a glacial slide has been provoked by the

[7] Abbé Gex has shown that the French and English term is a corruption of the old French term *lavanche*. This term, used in Savoy, Dauphiny, and Switzerland appears constantly in medieval chronicles latinized under the form *lavanchia*.

[8] I. C. Russell has studied accidents of the first class: Topographic Features Due to Landslides, *Popular Sci. Monthly*, Vol. 53, 1898, pp. 480–489; and Albert Heim accidents of the second: Über Bergstürze, *Neujahrsblatt der Züricher Natur. Gesell.*, 1882; Der Bergsturz von Elm, *Zeitschr. Deutsch. Geol. Gesell.*, Vol. 34, 1882, pp. 74–115. See also M. Neumayr: Ueber Bergstürze, *Zeitschr. Deutsch. und Oest. Alpenvereins*, Vol. 20, 1889, pp. 19–56; H. Ferrand: Histoire de la chute du Granier en 1248, *Ann. Club Alpin Français*, Vol. 9, 1882, pp. 580–602. Among the important accidents that of Flims is of the first class, those of Elm and Granier the second.

[9] P. Mougin: Les glissements de terrain, *Comptes rendus du Congrès de l'Alpinisme* (*Monaco, 1920*), 2 vols. in 1, Paris, 1921; reference in Vol. 1, pp. 423–433.

[10] André Chaix: Les coulées de blocs du Parc National Suisse d'Engadine (Note préliminaire), *Le Globe*, Vol. 62, 1923, Mémoires, pp. 1–35, Geneva, gives a bibliography completed by the account of A. Allix on that work, *Rev. de Géogr. Alpine*, Vol. 12, 1924, pp. 161–163.

[11] A. Lacroix: L'éruption du Vésuve en avril 1906, *Rev. Gén. des Sci.*, Vol. 17, 1906, pp. 881–899 and 923–936 It may be said that the term *coulée de lave* is, etymologically, a pleonasm.

[12] Such an avalanche takes place at the edge of "cliff glaciers" using this word in the restricted sense employed by W. H. Hobbs: Characteristics of Existing Glaciers, New York, 1911, p. 57. See also J. Brocherel: Éboulement et avalanches au Mont Blanc, *Augusta Praetoria*, Aoste, Italy, Vol. 2, 1920, 16 pp.

descent of a rock slide onto a glacier. This case, a true glacial flood, excepted, accidents of this kind in the Alps do not result in catastrophes analogous to those caused by snow because of the altitudes at which they take place.

Classifications of Snow Avalanches

Several classifications of snow avalanches have been proposed, a circumstance which in itself suggests that none has proved entirely satisfactory. One might almost say that every author has his own system, a new classification being *de rigueur* for each new work. As a matter of fact all the

Fig. 2—A small glacier avalanche on the summit of Ecrins (4103 m.), the upper part of the Glacier Blanc in Oisans. Note the man in the foreground. The camera was tilted at a large angle. (Photograph by A. Allix.)

classifications proposed bear more or less resemblance to one another, or rather are more or less easily recognized as pertaining to a single prototype—the classic division into *avalanches de poussière*, or *avalanches de surface*, and *avalanches de fond*. Hoek[13] gives the English rendering as "powdery avalanches" and "solid avalanches;" but, for the latter, "ground avalanche" would perhaps be more exact. This, the classification of Dr. Coaz and his followers, gives scientific form to a distinction long recognized by mountaineers. In the sixteenth century Josias Simler and, in the eighteenth century, Scheuchzer had already given expression to such an idea.[14]

[13] *Op. cit.*

[14] Josias Simler: Vallesiae et Alpium descriptio (1st edit., 1574), edited and translated by W. A. B. Coolidge in Josias Simler et les origines de l'alpinisme jusqu'en 1600, Grenoble, 1904.

J. J. Scheuchzer: Itinera per Helvetiae alpinas regiones facta annis 1702-10. 4 vols., Leiden, 1723. Cf. Hess, *op. cit.*, p. 305.

FIG. 3

FIG. 4

FIG. 3—"Snowslip" avalanche in the high mountain. Note the formation of *grelots*. (Photograph by courtesy of J. Gaberell, Thalwil, Switzerland.)
FIG. 4—"Fountain" avalanche below the Meije (3987 m., summit on the extreme right), Oisans. (Photograph by Nouvion.)

TABLE I—CLASSIFICATION OF AVALANCHE TYPES

State of Snow Before Departure		Departure				Course	Arrival				State of the Snow on Arrival	
							In single flow (*en un temps*)		In compound flow (*en plusieurs temps*)			
		Flowing	Rolling	Sliding			On slope	In ravine	On slope	In ravine		
Dry (cold avalanches)		Floury	Snowball (*boule*)	Snowboard (*planche*)	Short: Cascade; Long: Flow (*coulée*)	"Spout" (*en trombe*)*; "Fountain" (*en fontaine*); Superficial or lightning-flow (*coulée-éclair*)*; Deep (rapid flow)†	Simple cone or fan	Simple tongue (cf. glacial tongue)	Grooved cone	Grooved tongue	Homogeneous; In lumps: Clean, Earthy	
Wet (warm avalanches)	Light (fresh snow)		Snowball (*boule*)	Tile (*tuile*)	Long	"Fountain" cascade			Palmate cone		In lumps: Clean, Earthy, Woody, Earthy and Woody, Streaky	
	Heavy (old snow)			Snowslip (*foirage*)	Short Snow shield (*bouclier*)	Flood (*coulée*): Rapid†, Slow§						

* Powdery avalanche of usual classification. † Type of powdery-ground avalanche of usual classification. § Ground avalanche of usual classification.

Zdarsky has shown that the ground avalanche, in the ordinary sense, does not necessarily remove all the snow layer and, inversely, that the powdery avalanche may sometimes lay bare the surface. Hoek, again, has given more precise meaning to these two terms. He understands by powdery avalanche "that which is formed of fresh snow, light and fine; and by ground avalanche that which is formed of wet, compact, agglutinated snow." Dr. Paulcke, who in his manual of skiing distinguishes powdery avalanches, ground avalanches, and powdery-ground avalanches (*avalanches de fond poudreuses*), has given in the fourth edition of the celebrated work of Zsigmondy a classification of avalanches based on the condition of the snow: fresh (*Neuschneelawinen*) or old (*Altschneelawinen*). Avalanches of fresh snow fall into two categories according to whether the snow is dry or wet. Meyer von Knonau distinguishes four categories: powdery (*Staublawinen*), ground (*Grundlawinen*), sliding (*Schleichlawinen*), and "tile" (*Schlaglawinen*).[15] V. Hulin recognizes six: (1) *volante*, corresponding to the *Staublawine;* (2) *terrière*, corresponding to *Grundlawine;* (3) *mixte*, a combination of the two previous forms, corresponding to Paulcke's *avalanche de fond poudreuse;* (4) *rampante*, corresponding to the *Schleichlawine;* (5) *en tuile*, corresponding to the *Schlaglawine;* (6) *de surface*, corresponding to *Oberlawine* but including in Hulin's classification the case of the "balling" avalanche. Finally, the last classification, proposed by Max Oechslin, is simply a return to the first—surface avalanches (*Oberlawinen*) and ground avalanches (*Grundlawinen*).

Obviously all these classifications, which reflect more or less common observation and make use of popular expressions, are of an empirical character. Many authors, in particular P. Mougin, insist on the number of complex types which cannot be placed in set categories. As a matter of fact none of the above classifications is satisfactory because each has considered the question from one viewpoint only. The majority adopt as a basis the method of fall and neglect the condition of the snow; that of Paulcke-Zsigmondy takes the reverse stand.

Attempt at a Rational Classification

Now there is only one means of uniting the two principles of classification; that is to draw up a double-entry table, making a place for all possible combinations. It will be recalled that it was by this method that Rinne introduced clarity into the classification of eruptive rocks.[16] In the accompanying table I have attempted to place thus all forms of avalanches known to me either from personal experience or in scientific literature. The value of such a table depends in considerable measure on the choice of rubrics. As regards the state of the snow I have discarded Paulcke-Zsigmondy's subdivision though it is the only one along these lines proposed up to now.

[15] Gerold Meyer von Knonau: Erdkunde der schweizerischen Eidgenossenschaft, 2 vols., Zürich, 1838–39.

[16] Friedrich Rinne: Praktische Gesteinskunde, 2nd edit., Hanover, 1905. French adaptation by L. Pervinquière: Étude pratique des roches, 2nd edit., Paris, 1912.

* Powdery avalanche of usual classification. † Type of powdery-ground avalanche of usual classification. ‡ Ground avalanche of usual classification.

For age of the snow gives no indication of its condition, beyond a surmise as to its density. Fresh snow will give rise to very different types of avalanches according as to whether it is cold or warm, that is to say dry or wet. It is, I believe, this last distinction upon which the nature of an avalanche primarily depends. In making the distinction between dry and wet snow fundamental I am only conforming to an empirical classification which is well known to the mountaineer and which I am surprised not to have seen

FIG. 5

FIG. 6

FIGS. 5 and 6—Two unique photographs of powdery avalanches in descent. (Fig. 5 by C. Grauwiller, Grindelwald; Fig. 6 by W. Nehrkorn, reproduced by permission of R. Schudel, Grindelwald.)

discussed by any of the numerous theorists of the subject; only Charles Rabot mentions it incidentally—the division into cold avalanches (*avalanches froides*) and warm avalanches (*avalanches de chaleur*, which for correspondence of term I will call *avalanches chaudes*), it being understood that the term "warm" is purely relative. This mountaineer's classification is the only one in which the terms are mutually exclusive; that is to say in which combinations are impossible.

The cold avalanche comprises almost all occurrences classified by Coaz as powdery avalanches; it is more comprehensive than that of the simple superficial avalanche. The cold avalanche involves the movement of dry snow; it takes place in winter, most often during the time of greatest cold, and almost always coincides with a drop in temperature.

The warm avalanche is produced only when there is a thaw; it involves the movement of wet snow. Contrary to a widely held opinion, it can take place in winter as well as spring; it is incorrect to designate it "spring avalanche" as opposed to "winter avalanche." The warm avalanche includes the greater part of the avalanches classified by Coaz as ground avalanches.

In classifying according to conditions of fall the difficulty is to find place for the aborted avalanche, that is to say such as is arrested in the stage of departure. All alpinists know this as a very common case of which the type form is the *planche* of snow, the "snow board." It occurred to me that the point of view to adopt was that of the several stages of development. Heim had already distinguished the zones of departure, course, and arrival (*Abrissgebiet, Lawinenzug, Lawinenkegel*) but he had not utilized the distinction as a basis of classification. Used thus it permits us to distinguish, as no classification has done heretofore, the very varied forms presented by avalanches both in the course of their fall and after their arrest. The cone of the avalanche in particular assumes a great number of different forms, dependent on the mode of fall, surface topography, and nature of the snow.

The Starting Point, or Zone of Departure

Ski runners are well aware of the capricious variations of the snow surface. It needs but little experience to become acquainted with the rapidity with which it can change in consistency, density, cohesion, according to meteorological conditions and the time of day. It has been well said that on this subject even the most skillful ski runner has something to learn. These diverse aspects of the snow must be taken into account in classifying avalanches according to the zone of departure.

COLD AVALANCHES

Cold snow may be either fresh and light or old and compressed. In the latter case it is almost always congealed, more or less transformed into a bubbly kind of ice. It is exceptional that such snow slides. Cold avalanches are composed only of light snow that lacks cohesion. The snow may lie directly on the ground—a circumstance unfavorable to the formation of an avalanche but not necessarily prohibitive. It may rest upon a layer of older and harder snow, which affords an excellent sliding plane. Here arises the customary confusion between cold avalanches and superficial avalanches.

This snow, as we have said, is characterized by feeble cohesion. It may be floury in its entire thickness; it may be floury under a thin crust of harder snow or ice. When more compressed it will grind, hardening under the pressure of the skis; in this case it may again be homogeneous or crusted. According to Max Oechslin, who has made a critical study of the matter, fresh snow has a density of 0.07; and compressed snow, two days after

falling, a density of 0.20. Avalanches of floury snow are rare, because snow changes consistency a few hours after falling, becoming more coherent.

Schlagintweit (cited by Heim) established the category of "balling avalanche" (*avalanche en boule; Rolllawine*). V. Hulin took it to be a particular case of superficial avalanche. In reality its occurrence is rare, especially in cold snow, and it never attains significant dimensions. A foreign body falling on the surface of snow may determine the formation of a ball, which when once started rolling will continue to grow by the accumulation of more snow. But if the snow is coherent the ball will *always* be arrested before it has gone far, friction and adhesion exceeding the motive force. On the other hand if the snow is but slightly coherent and needs only to be put in motion, the disturbance caused by the rolling of the ball will soon enough determine the starting point of a normal avalanche (compare footnote 19). The motion of the normal avalanche itself almost always causes the formation of globular lumps of snow, *grelots*, of which more anon.

Cold compacted snow gives rise to the commonest initial form of cold avalanche, the *planche* of snow, "snow board," the *Schneebrett* of the German writers.[17] The layer of snow has the appearance of being cut up into a number of plate-like sections, the dimensions of which are on the order of 100 meters by 100 meters. This marquetry may result from alternations of temperature, with corresponding movements of expansion and contraction. It is most often produced in crusted snow, though this condition is not indispensable. The least disturbance, the simple cutting of a deep track by alpinists in single file may lead to the slipping of one of the sections of the marquetry. It will break away with a loud report like a rifle shot. The slipping of the snow in relatively coherent plates has naturally the effect of exercising vigorous compression in the lower part. This may be so violent as to give rise to a creaking noise—the snow "cries." The lower part of the snow board plowing forward raises a series of eddy-like waves. The alpinist taken by surprise loses his equilibrium at the arrival of the first of these eddies; he is swept off his feet and plunged head downwards into the mass of moving snow in which he may be buried by successive waves unless he keep on the surface by a swimming motion.

In the lower parts of the avalanche the snow is powerfully compressed. As Tyndall's classic experiments demonstrated, compression causes congealing. However light it was at the point of departure the snow then always becomes hard as ice. M. Pierre Lory told me his experience on Belledonne where he was surprised by a diminutive avalanche. The movement of the hard snow wrenched the ice axe from his hand with an irresistible force.[18] It is this hardening of the snow that renders death almost inevitable if rescue is not at hand, for the alpinist thus caught who is not able to regain the surface finds himself paralyzed in a sheath of ice. Victims who sink in deeply can only be reached by rare good fortune.

[17] Excellent photograph in the work of Hoek and Richardson. Dr. Hoek has given the best descriptions of the phenomenon and has proposed the English equivalent snow board (*op. cit.*).

[18] See also the account by Mrs. Clark, cited below, footnote 44.

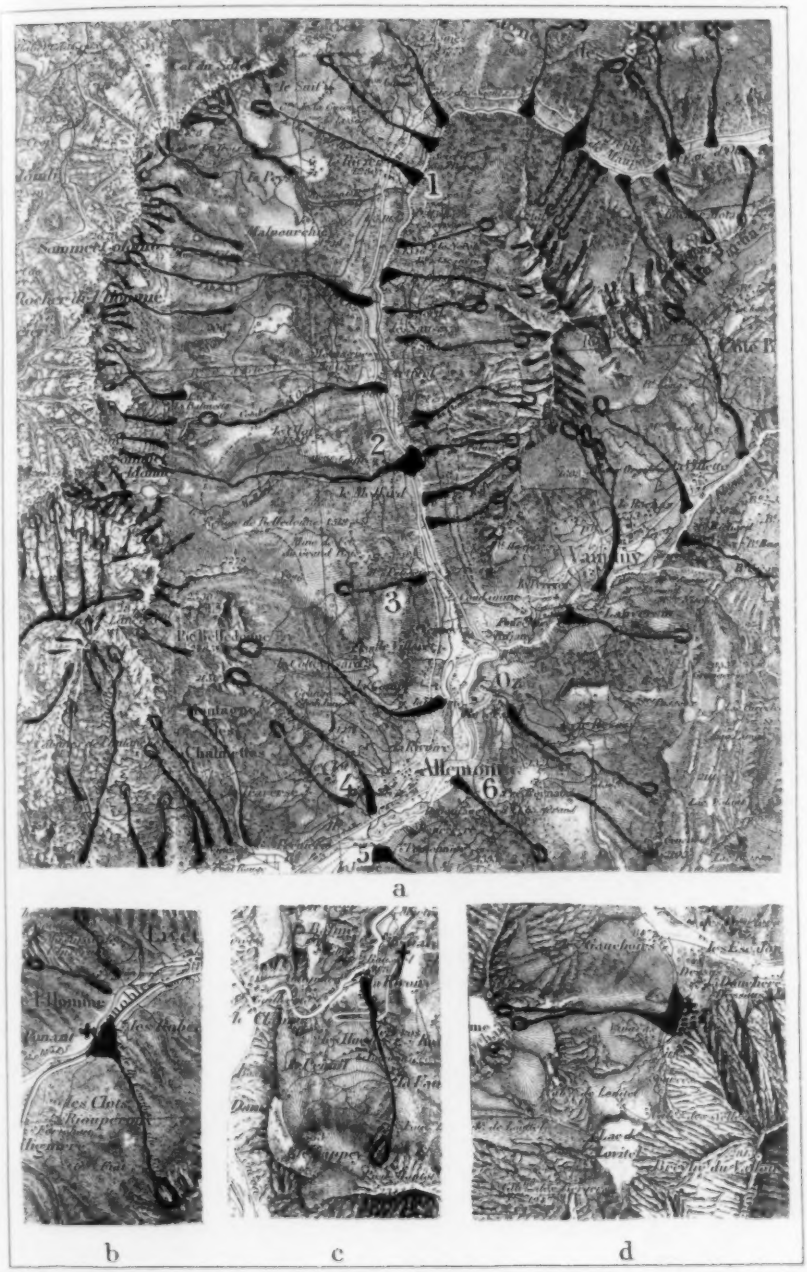

FIG. 7—Avalanches in the Oisans region, east of Grenoble, shown on the French General Staff map 1: 80,000 (slightly reduced). *a*—Avalanches of 1923 in the valley of Eau d'Olle. Numbers have reference to photographs: 2 is shown in Figure 26, 3 in Figure 21, 4 in Figures 29 and 30, 5 in Figure 12, 6 in Figure 22. *b*—Avalanche of Roberts, Livet, March 3, 1923. The cross indicates the point whence the photograph Figure 25 was taken. See also Figure 27. *c*—Avalanche of La Rivoire, Mont-de-Lans, March 3, 1923. The cross indicates the point whence the photograph Figure 13 was taken. See also Figures 19, 20, 32, and 33. *d*—Avalanche of La Dauchère, Venosc, February, 1904 (after data by Pierre Lory). The dashes indicate the course taken by the "wind of the avalanche," the cross the point whence the photographs Figures 10 and 11 were taken.

FIG. 8—Avalanches on the Col Ornon, Taillefer massif (Dauphiné), May 3, 1923, two months after their descent. (Photograph by V. Hulin.)

When thus compressed, crushed, and overturned the snow plates break up, assuming the form of more or less rounded lumps usually the size of a man's head or even larger (Fig. 3). These *grelots*, as V. Hulin has termed them, are characteristic of the snow of avalanches. It is exceptional that the snow slides in a homogeneous mass without the formation of *grelots:* this happens practically only in the case of floury snow.

WARM AVALANCHES

Warm snow is always damp. Consequently it is more cohesive than cold snow. It is also heavier. Max Oechslin gives 0.45 as the density of fresh

FIG. 9—An avalanche at Petites Sables (Oisans), December 31, 1922. No damage has been done to the wood through which it has passed.

wet snow, and 0.70 to 0.85 for old wet snow compacted by pressure. This snow may be more or less water-soaked, more or less granular, more or less "sticky" to the skis; it may be either crusted or uncrusted. It slips in masses, larger and slower in movement than the cold snow. Warm snow never has a floury appearance. When rolling balls are formed in this kind of snow they have exactly the same character as those formed in cold snow and the comments made above in regard to them are applicable here.[19]

A type of avalanche peculiar to warm snow is the *tuile* or tile. Wet snow *always* slides on the slopes that it covers, though this movement may

[19] "I cannot sufficiently emphasise the fact that a 'balling' avalanche never occurs—no such thing as a house-high giant's football." (Hoek, *op. cit.*, p. 382, note.)

be very slow. P. Mougin and Max Oechslin have both made investigations thereon.[20] The phenomenon may be observed in winter on any house roof—on any snow-covered slopes, in fact, provided the inclination is sufficient. On the edge of the roof the layer of snow slips down and overhangs for a time until the force of cohesion is overcome, when it breaks, precipitating a "tile" of snow on the ground or the heads of unwary passers-by. This little accident is common enough in the alpine regions and is the reason why the roof slopes are generally broken up by horizontal laths or bordered by little parapets.

On a continuous slope the rupture of the layer of wet snow is followed by a rapid sliding which accelerates to a velocity limited by friction and the varying inertia of moving snow. This is a phenomenon quite comparable to that of the snow board, although it is slower, and it always leaves the ground exposed (Fig. 3).[21] It is similar enough to a landslide, and I suggest expressing it by the same term *foirage*, rendered in English by "snowslip."

As in the case of earthy material the *foirage* may be shortly arrested and compacted in place (Fig. 3). Such a condition may be termed *bouclier*, "snow shield" (*Schneeschild*). It appears to me best to limit the term thus rather than apply it as Hoek and other German writers have done to the cold snow board. If the snowslip continues its course, it develops snow waves and breaks up with the formation of *grelots* as in the snow board.

Before turning to the second stage we must state the degree of slope which permits the formation of rapid slides. Hoek defines as dangerous a slope of 23°; Rütgers places it between 22° and 25°. Max Oechslin has observed the departure of an avalanche on bare frozen ground on a slope of about 16°. It would appear, however, that such a case is exceptional and that the normal value of the critical angle is the average given by Hoek.

Zone of Course

The snow board or the snowslip, as we have seen, can be arrested in the departure stage when we have what I propose to call "short" slips. If the snow continues its progress we have "long" slips, which are transformed into flows. Rarely does the flood of snow spread over a broad slope (Fig. 3). Most often it sooner or later molds itself into a ravine; this is the *couloir* or chimney of the avalanche. Hobbs uses the term *couloir* to express this idea in English; it would appear to me preferable to use the term "gully" for the former word and "funnel," suggested by Hoek, for the latter.

[20] This sliding has never been clearly observed for absolutely dry snow. It is probable that it takes place, but the lack of cohesion renders impossible the phenomenon of the *tuile*, it being replaced by the cascade of powdery snow.

[21] Max Oechslin has an interesting photograph of a slide of this nature on its way, leaving bare the ground behind it.

COLD AVALANCHES

It often happens that the gully of the avalanche is interrupted by an abrupt break in slope. In such case the snow is precipitated forward as a "waterfall" of snow coming to rest with the noise of a thunderclap. With very floury snow the cascade may appear as suddenly as a dust whirl. The crystals of snow are so light and loose that they whirl in the air like dust. Photographs of such cases are very rare (Figs. 5 and 6).

When the snow is a little more compacted and when it is composed of lumps the cascade is slower and more continuous. From afar it may closely resemble a waterfall in appearance though the wind raises only a little white dust about it. This I propose to term "fountain" (Fig. 4). The "fountain" may run for several hours, even days, with occasional interruptions; it produces a rumbling noise, dull and intermittent.

When the slope is regular there is only a flow. The snow may be powdery or in lumps; if the former it will be accompanied by a great flurry of snow dust. Sometimes the speed acquired is sufficient to raise the entire mass of snow in the air. This is the avalanche of snow dust proper (Fig. 6). It is most likely to happen where powdery snow slides over a surface of old snow and thus attains great speed. I have given this form the term "superficial flow" (*coulée superficielle*) or lightning flow (*coulée-éclair*). The speed attained may be 300 to 400 kilometers an hour.

When dry snow slides over the ground leaving it bare the movement is slower, though still comparatively rapid, and gives rise to less flying dust. It corresponds to the powdery-ground avalanches produced in cold snow. I call it "deep flow" (*coulée profonde*) or "rapid flow" (*coulée rapide*). Its velocity ranges from 100 to 200 kilometers an hour.

WARM AVALANCHES

It sometimes happens that lumps are not formed in light snow. This is when the snow is very wet and flows as a semi-liquid, like a sherbet, having a homogeneous consistency (Figs. 9, 23, 24). But in the vast majority of cases, and invariably when the snow is dense, lumps are formed. The warm avalanche may descend as a cascade when the relief is suitable, but the fall in such case is slow and continuous—a fountain. I have described elsewhere one that flowed for more than three weeks before being replaced by a waterfall.[22] In Figure 8, a view taken in spring, are cascades of water along the gullies where earlier flowed the snow fountains.

Light wet snow gives rise to rapid flows that attain speeds of 100 to 200 kilometers an hour. Examples are known where such snow slides over an underlying layer of old snow; snow dust is then produced. This category includes all powdery-ground avalanches formed in warm snow.

Heavy wet snow always flows more slowly. The "slow flow" (*coulée lente*) of the table has a mean velocity of 20 to 50 kilometers an hour.

[22] Allix, Les avalanches de 1922–1923 en Dauphiné, *Rev. de Géogr. Alpine*, Vol. 11, 1923, p. 520, Fig. 10.

FIG. 10—Complex avalanche that fell at La Dauchère. Venosc, Oisans, February, 1904. Note on the left the wall of snow, six meters high, piled up by successive flows of the first avalanche (heavy wet snow). Four days later a powdery avalanche cut a deep striated furrow across the earlier cone. Compare Figure 11. (Photograph by Pierre Lory.)

of the first avalanche (heavy wet snow). Four days later a powdery avalanche cut a deep striated furrow across the earlier cone. Compare Figure 11. (Photograph by Pierre Lory.)

FIG. 11—Effect of the "wind of the avalanche" that accompanied the second avalanche at La Dauchère (Fig. 10). See Figure 7*d*. (Photograph by Pierre Lory.)

Speed is retarded not only by its weight and its adhesion to the ground but by the foreign bodies it plucks up and carries along—earth, rocks, trees. J. Brocherel asserts that an avalanche of this sort, heavily laden, may flow with the slow majesty of a lava stream; though I myself have never observed such slowness of motion. Avalanches of wet heavy snow form the classic category of ground avalanches.

Both slow and rapid avalanches may slide with a single motion. This I have termed the "single flow." Most often descent is accomplished by several consecutive flows. Strangled at the opening of a ravine too narrow to accommodate its bulk the snow divides into masses which, being thrown about, knocked together, and hurled against the sides of the ravine, behave in an astonishing way and later on take most surprising forms. Abbé Gex has given a lively description of this smashing up of the avalanche by itself.[23] This I have termed the "compound flow." The successive flows are differently charged with foreign matters, some perhaps being constituted of pure snow; hence here is a distinct banding in the zone of arrival, where the course of the avalanche is finally arrested.

Zone of Arrival

In the zone of arrival warm and cold avalanches give rise to the same forms. Differences in form depend on the mode of fall and on the relief of the ground whereon the avalanche falls.

Falling at the foot of a slope the avalanche will produce a cone, or fan, of snow. If arrested in the ravine the form resembles the tongue of a glacier. The single flow gives a simple cone (Fig. 8, to left; Fig. 9) or a simple tongue. The compound flow results in a grooved appearance; this may be termed the "grooved cone" and "grooved tongue." The grooved cone is much the more common (Fig. 12), but the grooved tongue is also frequently seen (Fig. 20). The photograph, Figure 10, presents a magnificent example of a grooved cone whose genesis is exceptionally interesting.[24] This phenomenon took place at La Dauchère (commune of Venosc en Oisans) in the Lauritel valley, in February, 1904. A first avalanche of heavy wet snow (ground avalanche) produced a great grooved cone. Four days later, following a considerable drop in the temperature and a fall of snow, a cold avalanche (powdery avalanche) occurred on the same spot and traced an enormous groove on the earlier cone, thus constituting what is in fact a double-grooved cone.

Sometimes the occurrence of powdery and ground avalanches is practically simultaneous. It may happen that the fall of a cold avalanche from a great height starts the descent of an avalanche of heavy wet snow in lower and warmer regions. Rarely, however, can the two phenomena be distinguished in such case, for the former is generally of smaller volume and

[23] F. Gex: Les avalanches en Savoie durant l'hiver 1922–1923. *Rev. de Géogr. Alpine*, Vol. 11, 1923. pp. 487–511.

[24] For this unpublished photograph and accompanying data I am indebted to P. Lory; see footnote 36.

is absorbed by the latter. More commonly one sees an avalanche of wet light snow at a high elevation start in train lower down an avalanche of heavy wet snow. The coincidence of powdery and ground avalanches is generally to be interpreted this way. G. Brocherel has a beautiful photograph taken at Courmayeur in which are seen side by side gullies occupied respectively by a powdery avalanche and a ground avalanche leading to a single-grooved cone.

FIG. 12

FIG. 13

FIG. 12—Avalanche at La Voute d'Oz, Oisans, on March 3, 1923. The scar marking the point of departure has been lightly reinforced. See Figure 7*a*, No. 5. (Photograph by V. Hulin.)

FIG. 13—Avalanche at La Rivoire, Mont-de-Laus, Oisans, on March 3, 1923. The scar marking the point of departure has been lightly reinforced. The cross in the foreground marks the site of a house overwhelmed and destroyed (Figs. 32, 33). See also Figure 7*c*. (Photograph by V. Hulin.)

When the snow is not very abundant, or when the successive flows travel with very different speeds, some go farther than others and are apt to follow divergent tracks. This is less easy to observe in winter when the ground is covered with a mantle of snow, but it is apparent enough in the spring when the superficial snows have melted and only the accumulated masses of the avalanches survive. It gives rise to a special type of cone rarely mentioned in spite of the frequency of its occurrence; I propose to term it "palmate cone." Figures 17 and 18 show two views of a true palmate cone; Figure 16 has side by side with a true palmate cone a false form produced by the confluence of two avalanches, one of which has partially ridden over the other.

The uninformed observer might imagine that the cone of the avalanche is of much greater dimensions than the little scar in the form of an inverted

tear left high up on the mountain slope by the snow as it departs (Figs. 12, 13). Hence the belief in the existence of tributary avalanches which swell the main flow. In reality it is only an optical illusion due to perspective, and the error may be corrected by examining the map (Fig. 7). The case of a tributary avalanche is rare; two are figured on the map, Figure 7*a*, one to the south of Belledonne—which, however, is hypothetical, for this valley is inaccessible in the season of avalanches—and the other above Vaujany.

Tongues and cones present very different forms and attain very different distances in successive years. The avalanche shown in Figure 12 most often forms a tongue in its ravine; in 1906, however, the flow, while much thinner than in 1923, traveled farther. Figures 17 and 18 show the same palmate cone in 1923 and 1904 respectively; sometimes it appears as a tongue, sometimes as a cone. When a flow is launched with particularly high speed, instead of stopping at the foot of the slope it may be carried a distance up the opposite side. About 1860 the avalanche of Roberts in Oisans (Fig. 7*b*) crossed the bed of the Romanche and carried great tree trunks to a height of more than fifty meters up the opposite bank.

In the zone of arrival the snow may be homogeneous, but most often it has the customary form of globular lumps. Heim, who has remarked their abundance (*ein ungeheurer Zahl von Schneeballen*), shows that they may affect the most varied forms: balls, discs, ellipsoids, cylinders, etc. But when alternate thawing and freezing has been in progress for some days (and this has generally been the case when the cone is studied) the form of the lumps tends to be regularized (Fig. 14). Exceptionally they attain great size, dimensions on the order of a cubic meter (Fig. 15). These are produced, I believe, in the last stages of the fall of a light, very wet snow compacted suddenly towards the end of the descent.

Simple cones may be composed of pure snow or of snow charged with various materials collected in the descent. Grooved and complex cones often present a streaky appearance, each flow having reacted in its own particular manner to the surface over which it progressed (Fig. 24). Generally the latest flows are those bearing most earth, but there are exceptions. On the right hand side of Figure 8 is seen a small earthy cone; Figure 21 shows an avalanche charged with wood; Figure 28 an earthy and woody avalanche.

The cone of the avalanche takes long to melt; sometimes a residuum remains from year to year. P. Mougin has noted an avalanche that fell in 1860 in Upper Tarentaise and served as a bridge across the Isère for seventeen months. Nothing is more dangerous, as Abbé Gex has pointed out, than the exploration of one of these cones. When the avalanche falls the lumps are often massed together in unstable equilibrium, the hollows being concealed. Again the melting snow is usually sapped from below with the formation of snow grottoes, and the rash tourist proceeding onto the surface falls through. When melted the cone of the avalanche leaves behind a more or less extensive débris of earth and wood, the "crasse" (Gex).

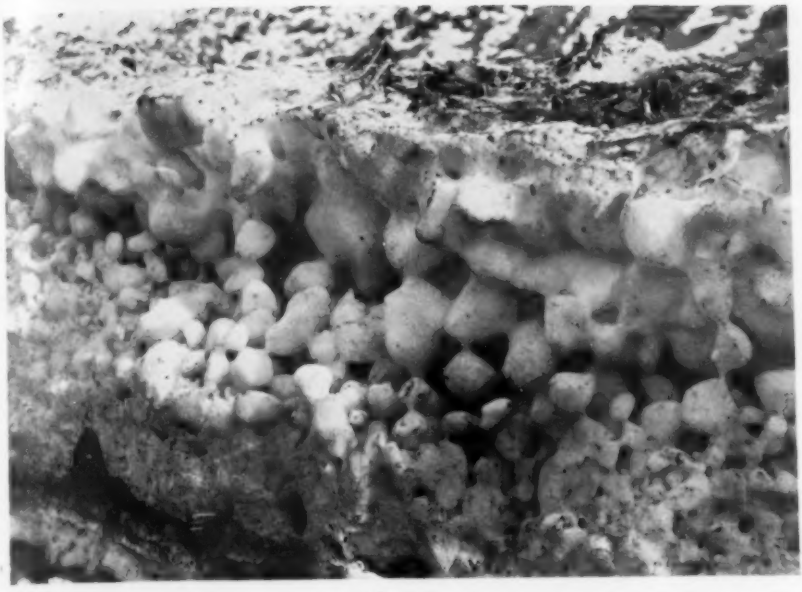

FIG. 14

FIG. 15

FIG. 14—The interior structure of a ground avalanche: *grelots*, lumps of snow rounded and united by several days of alternate thawing and freezing. (Photograph by J. Brocherel.)

FIG. 15—Large balls of snow remaining in a half-melted avalanche at Villard d'Entraigner (Dauphiné), 1911. For size note the man in the middle of the scene. (Photograph by V. Hulin.)

FIG. 16

FIG. 17

FIG. 18

FIGS. 16, 17, and 18—Palmate cones of avalanches in the Romanche Valley, Oisans. Figure 16 shows the avalanche of Treuil in April 1923, six weeks after its descent, and Figure 17 similarly the avalanche of Vaudaine. (Both photographs by V. Hulin.) Figure 18 shows the avalanche of Vaudaine in 1904. (Photograph by Pierre Lory.)

Frequency of the Various Types

It is difficult to give even an approximate idea of the relative frequency of the several types of avalanches. Coaz and Mougin have both attempted an estimate, from which it appears that ground avalanches are much the most numerous. In Savoy during the period 1900–1901 to 1913–1914, out of an annual average of 586.4 avalanches Mougin classed 421.3 as ground avalanches, 31.5 as powdery, 131.8 as superficial, and 1.8 as glacial. That is ground avalanches constituted nearly 72 per cent. It will of course need several years' observation before percentages can be given according to the author's classification. The predominance of avalanches of heavy wet snow may be explained by the fact that they are often provoked by the occurrence of other types.

Effects of Avalanches: Are They Beneficial?

All told, the avalanche is a subordinate type of phenomenon, and interest in it must be considered purely theoretical unless it has a powerful reaction on the conditions of life in the mountains. One may first ask if it has any favorable effects in this regard. An old theory has led many authors to answer this question in the affirmative. Tschudi, cited by A. de Quervain, states specifically that "the devastation wrought is insignificant compared with the benefits bestowed." Abbé Gex, an observer of the first rank, recently revived this theory, though he does not appear to have been aware of Tschudi's text nor the criticisms of Coaz and de Quervain.[25] He does not go as far as Tschudi (and more recently V. Hulin) to say that the chief rôle of the avalanche lies in the favoring of vegetation by premature removal from the mountains of their encumbering mantle of snow;[26] but in his opinion the residual earth and wood left by the avalanches afford compensation in fertilization of the soil and provision of fuel. He also specially mentions the function of the masses of snow as valuable reservoirs of water capable of regulating, if not of increasing, the discharge of springs and streams. He even designates these masses of old snow as "infant glaciers," a pretty expression but one likely to convey a false idea. Comparison to a miniature glacier may be useful to describe the appearance of the avalanche tongue in a ravine,[27] but it only holds good from the descriptive point of view. On scientific grounds, whether glaciological or hydrological, it is adventitious; structure, motion, effects are in no wise similar.

[25] F. Gex: Rôle et utilité des lavanches, conclusion (pp. 169–178) of the article "Les avalanches du rebord subalpin de la Combe de Savoie." *La Géographie*, Vol. 39, 1923, pp. 36–52 and 165–179. See also *idem:* Les avalanches en Savoie durant l'hiver 1922–1923, *Rev. de Géogr. Alpine*, Vol. 11, 1923, pp. 487–511.

[26] According to Coaz the proportion of snow carried off by avalanches is at the maximum a quarter of the total snow surface. A. de Quervain (*Sport*, 1922) reduces the figure to one-tenth. It appears to the writer that this should be still further diminished.

[27] Cf. Allix, Les avalanches de 1922–1923 en Dauphiné, *Rev. de Géogr. Alpine*, 1923, p. 520 and Pl. iv, Fig. 11. See also Figure 13 of this article which represents the same tongue from another viewpoint.

Hydrologic and Climatic Rôle

It is, however, incontestable that avalanches in which the snow is congealed conserve a certain quantity of water where they fall. If such snow had remained in a thin layer on the slopes it would have melted with the first warm days of spring; accumulated in thick packets and well sheltered at the bottom of a ravine it may take all summer to melt, and a residuum may indeed last the year round. As a practical matter an attempt has been made to estimate the quantity of water thus put in reserve. The reforestation service with Grenoble foresters under the direction of V. Hulin has undertaken studies of this nature by setting up bench marks. In the ravine of Vaudaine (Oisans) systematic observations have been undertaken, following the method employed for estimating the frontal variations of glaciers. It is still too early, however, to draw conclusions therefrom.

But the beneficent hydrological rôle does not appear to be very considerable at first glance. Really to evaluate it, it would be necessary to compare the discharge of streams from a given basin in years when there were many avalanches with the discharge in years when avalanches were few, and this has not yet been done. Offhand it would seem that the snows of avalanches would swell the streams only in the summer season when they are already well fed by glacial melting and that the avalanche's rôle of regularization is thus very limited: it is in winter that the alpine streams lack water. Only a small part of the melted water of spring could be kept till summer, and that is not very certain. It has been shown that a great part of the summer flood even in the high mountain comes less from the melting of glaciers or masses of snow than by restitution of the spring waters absorbed by the soil.[28] Now these spring waters are almost entirely derived from the melting of the snow cover. Preserved in the soil or in avalanche cones, I believe that the water coming from the snow arrives at practically the same moment in the streams and thus that the regulating rôle of the avalanche is reduced to insignificance.

Great avalanches have another hydrological effect, considerably less important in its consequences because of its brevity but very striking at the time of occurrence: this is the temporary damming up of stream beds (Fig. 22). In March, 1923, the Vénéon in Oisans abruptly ceased to flow for more than an hour, and this was the only indication one had downstream of the occurrence of a great avalanche in the upper valley. It is rare, however, that a stream is interrupted for long in this way.

Important climatic effects have also been attributed to avalanches, notably a lowering of temperature in years when avalanches are numerous. A. de Quervain, a master of the subject, has done justice to this hypothesis. A winter of heavy snows may have an influence on the temperature of the following summer, as on the alimentation of glaciers; but the effect of ava-

[28] André Allix: La crise de la houille blanche dans les Alpes françaises, *La Géographie*, Vol. 39, 1923, pp. 307–320.

lanches in this respect amounts to nothing. The lowering of temperature is strictly local: it is only over a radius of some dozens of meters[19] that a sensible retardation in the development of vegetation can be recognized.

FIG. 19

FIG. 20

FIGS. 19 and 20—Gouging action of a ground avalanche in earth and snow respectively. Avalanche of La Rivoire, March 3, 1923. (Photographs by A. Allix.)

MORPHOLOGICAL EFFECTS: EROSION BY AVALANCHES

On the contrary, direct observation shows that avalanches are capable of exerting a powerful morphological action. Up to now this action has invariably been underestimated. In an article otherwise fundamental M. de Martonne makes only brief allusion thereto.[20] Abbé Gex places the morphological action of avalanches at much less than that of running water in the same channels. This opinion I do not share.

[19] Gex, Les avalanches du rebord subalpin de la Combe de Savoie, *La Géographie*, 1923, p. 176.

[20] Emmanuel de Martonne: Le rôle morphologique de la neige en montagne, *Comptes rendus du Congrès de l'Alpinisme* (*Monaco, 1920*), 2 vols. in 1, Paris, 1921; reference in Vol. 1, pp. 335–344; and *La Géographie*, Vol. 34, 1920, pp. 255–267. It may be remarked, however, that this work, which deals with entirely original matters, expressly omits avalanches as a subject already well studied.

The sides of the high mountains are generally ravined by gullies known to alpinists, by whom they are carefully avoided, as avalanche gullies (*couloirs d'avalanches*). Possibly subaerial action, especially alternate freezing and thawing, accomplishes more work here than the occasional friction of falling masses of snow: usually gullies particularly dangerous because of avalanches are likewise dangerous because of falling stones. Again, below a certain altitude the action of meteoric water is clearly recognized in the ravines. Yet there appear to be cases where sliding of the snow acts alone as an erosive force, or at least has the preponderant

FIG. 21—An avalanche loaded with trees after traversing a forest. Combe-Longe, Allemont, Oisans, March 3, 1923. See Figure 7*a*, No. 3. (Photograph by V. Hulin.)

rôle. Reference may be made to a number of classic illustrations, views taken near the crests of high snowy mountains; the Canadian Rockies, the Himalaya,[31] and the New Zealand Alps.

If a rock can be found that is practically unaffected by the work of running water in a position where avalanches are a characteristic phenomenon, one has a test case of their erosive power. Now such a rock does exist. Long ago I called attention to a wall of fissured limestone, in Vercors (French Prealps) between the Col de l'Arc and the Col Vert, which is furrowed each spring by multiple avalanches. It exhibits a relief etched in parallel channels similar to the classic form that Sven Hedin has described in the countries of eolian erosion under the name *yardangs*. I do not believe that it is possible to interpret these forms other than as the work of avalanches.[32]

Furthermore, the powerful erosive action of a snow flow is manifested by its gouging action on the walls of the gully in which it flows (Fig. 19).

[31] See in particular several photographs of the British Expedition to Mt. Everest; notably that of Makalu facing p. 226 of "Mount Everest: The Reconnaissance, 1921," London, 1922. See also André Allix: Les enseignements du Mont Everest, *Rev. de Géogr. Alpine*, Vol. 12, 1924, pp. 99–128.

[32] André Allix: La morphologie glaciaire en Vercors, *Recueil des Trav. de l'Inst. de Géogr. Alpine*, Vol. 2, 1914, pp. 1–185. These forms are much too extensive to be mistaken for enlarged lapiés.

P. Mougin has already demonstrated this clearly.[33] This action, however, is not to be confused with the grooves cut across the cone by a compound flow; Figure 20 shows the two phenomena side by side.

F. Gex has made the just observation that the avalanches of a ravine contribute to facilitate subsequent transportation by water; but they themselves also exercise a considerable plucking action (Fig. 28). The work of the avalanche is over in a moment; but during this moment I estimate that it can pluck more earth than the stream in the ravine during an entire year. P. Mougin has measured the amount of material dropped by avalanches in

FIG. 22—Avalanche of Boulangeard d'Oz, Oisans, in the bed of the Eau d'Olle, March 3, 1923. (Photograph by V. Hulin.)

the inhabited valleys of Savoy since the winter of 1907–1908. In four years, that is up to 1912, the total volume of earthy material thus carried amounted to 43,430 cubic meters, in the single year 1909–1910 measuring 23,079 cubic meters. Ground avalanches transported about 79 per cent of the total, and glacial avalanches (which are not included in the present study) about 18 per cent. The avalanche of Blaitière (Chamonix) on April 3, 1914, alone carried more than 2000 cubic meters of earth, rocks, and boulders.

Yet this action must not be exaggerated. Taking an opposite stand from that of Abbé Gex, Professor W. H. Hobbs suggests in a letter dated January 24, 1924, that "the avalanches from hanging valleys into the main U valley would seem to be earlier stages to the slide down of the U walls in successive slices, as for example in the Flimser Bergstürz."[34] I believe that there is here a confusion between the avalanche of snow and the landslide. The erosive action of the former is more modest but is undeniable: the appearance of an avalanche-furrowed slope in summer is convincing enough.

[33] Mougin, Les avalanches en Savoie. See also Allix, Les avalanches de 1922–1923 en Dauphiné, *Géogr. Alpine*, Vol. 11, 1923, pp. 513–527.

[34] W. H. Hobbs: Characteristics of Existing Glaciers, New York, 1911, p. 93.

The avalanche exercises its erosive action from back to front, comparable to that of a carpenter's plane. This is, I believe, the only case in nature of this form of erosion. One sometimes speaks of "gouging" action to describe the sculpturing work of a glacier on the surface over which it travels. Such a comparison is out of date and quite inapplicable to a glacier whose kinetic energy is very feeble;[25] but it is perfectly appropriate to the avalanche, which possesses enormous energy.

Destructive Power of Avalanches

It is curious that in all discussion regarding glacial erosion no physiographer has advanced this simple-enough idea of kinetic energy. It is expressed, as one knows, by the equation $f = \frac{mv^2}{2}$, in which m represents the mass in movement and v the velocity. The advantage of the avalanche, the speed of which is enormous, over the glacier, of much greater mass but insignificant velocity, is obvious.

Attempts have often been made to measure the volume of avalanches. Coaz, Heim, and Mougin give values for the larger avalanches ranging from 150,000 to 1,000,000 cubic meters. P. Denza, cited below, gives as much as 3,000,000 cubic meters for the avalanche that descended at Venaus, Italy, in the spring of 1885. The Service of Bridges and Roads of Grenoble gives the modest estimate of 200,000 cubic meters for the volume of the great avalanche of Roberts de Livet in March, 1923 (Fig. 25). We shall adopt this figure as representing an acceptable average for the greater avalanches. If such a mass should consist of powdery snow it would have a weight of 14,000 tons; old snow would have a weight up to 160,000 tons.

Now, as we have instanced above, these masses are displaced with high velocity. Actual measurements are rare; the figures already mentioned are based on observations by Coaz (1910) and by P. Mougin. I have myself made two such measurements. On May 7, 1922, on the Meije I observed an avalanche of light wet snow that traveled 3.25 kilometers in 74 seconds, that is at a rate of about 160 kilometers an hour. On January 27, 1921, the avalanche of Mollard (Fig. 7*a*) in heavy wet snow traveled 4.8 kilometers of its course in a little less than 6 minutes, that is at a velocity of 48 kilometers an hour. Slope evidently is a very important factor in acceleration or retardation of the rate; in the first case the average slope was 45°; in the second 30°. An average course for a large avalanche measured along the slope may be said to range between 2500 and 4000 meters. That of Mollard was exceptionally long. The corresponding change in level may range from 1500 to 3000 meters.

If it be assumed that a large ground avalanche descends through 2000 meters with a speed of 10 meters a second and mass approximating that of Roberts, its energy can be estimated at about 20,000,000 horse power. If

[25] The great morphological action of a glacier is due to other causes on which I have submitted other hypotheses (Observations sur la sculpture du relief par les glaces, *Comptes Rendus de l'Acad. des Sci. [de Paris]*, Vol. 174, 1922, pp. 233–235 and 689–691).

the figure of 3,000,000 given for the avalanche of Venaus is correct, the corresponding energy would be 300,000,000 horse power. For comparable effects in other phenomena one has to turn to volcanic eruptions, great landslides, the breaking up of pack ice or icebergs, tidal waves, the breaking of hydraulic dams. The recent catastrophe at the Lake of Gleno in Italy possessed not more than four or five times the energy of the avalanche of Roberts and was apparently inferior in this respect to that of Venaus.

FIG. 23

FIG. 24

FIGS. 23 and 24—Two views of an avalanche in a wood, Val Cluoza, Switzerland. (Photographs from the Swiss Alpine Club.)

Hence the avalanche must be classed as one of the great destructive forces of nature. It is as capricious as a stroke of lightning. On the occasions when the "wind of the avalanche" is added its effects are entirely unpredictable. The flow of snow itself plays strange pranks on man. That disasters are not more frequent is because avalanches generally follow fixed tracks which one has learned to avoid.

THE AVALANCHE WIND

Sometimes the avalanche expends its force on the ground and remains inoffensive, while the column of air displaced by the fall ravages a considerable area. Nothing gives a more vivid idea of the speed and mass of an avalanche than these sudden hurricanes. Naturally it is the powdery avalanches which give rise to the most violent blasts of air because of their exceptionally high speed; in fact, this is generally the form in which this type of avalanche accomplishes its work of destruction. One can take shelter from the flows of snow; it is more difficult to escape the blasts of air so capricious and unpredictable are they. A number of photographs showing the effects of the avalanche wind have been published, the best of them by J. Brocherel. One may see, for instance, the snow plastered with such

violence against a vertical wall as to cover it with a thick crust; or forest trees lopped down by a single blow at a distance of 500 meters from the avalanche itself, reminding one of the forests destroyed by artillery during the war. We have the good fortune to include here a splendid photograph heretofore unpublished, taken by M. Pierre Lory, Figure 11.[36] This devastation was accomplished by the avalanche of La Dauchère, to which reference has already been made. It was the second, or powdery, avalanche that furnished the blast of air. As Figure 10 and the map Figure 7*d* show, the flow of snow turned at right angles down valley. But the blast of air

FIG. 25—A great ground avalanche at Roberts, Livet, Oisans, which crossed a highway. Photograph taken March 16, 1923, fifteen days after the descent. Pedestrians are seen on the temporary road constructed over the avalanche (for a closer view see Figure 27). See Figure 7*b*. (Photograph by A. Allix.)

continued on in a straight line almost completely mowing down the larch forest covering the ridge seen in Figure 11. The hamlet of La Dauchère lies between the current of snow and that of air as between the forks of a Y and thus escaped destruction.

The force of the wind in a ground avalanche is less powerful. P. Mougin goes as far as to deny its existence. Yet on March 3, 1923, the avalanche of Roberts (Fig. 25) turned head over heels a workman who was passing at a distance of more than 50 meters. This man had been knocked down during the war by the blast from a shell, but he gave the palm for violence to the avalanche!

Some reports state that the avalanche wind has been felt at a distance of many kilometers along the valley in which the avalanche falls. This I do not venture to corroborate; it rests on testimony that is always subject

[36] I am especially indebted to my distinguished friend, Pierre Lory, whose advice has been invaluable to me during the fifteen years that I have studied the mountain. Worthy heir of a great name, this celebrated Grenoble geologist has the modesty to leave to others publication of the results of his own work, as in the present instance. All the data regarding the avalanche of La Dauchère are due to him; on it he has published only a short note, the summary of a lecture given before the Société de Statistique de l'Isère, June 13, 1904 (*Bull. Soc. de Statistique du Département de l'Isère*, Series 4, Vol. 8, 1904, pp. 583–584). On the avalanche of La Dauchère see also the Chronique alpine of F. Durtein (Henry Duhamel) in *Le Dauphiné*, April 17, 1904.

to exaggeration. One thing, however, is indisputable: that damage to forests has been accomplished at distances of about one kilometer. Moreover, the avalanche is itself a great enemy of the woods.

The Avalanche and the Forest

The ravines traversed each year by avalanches are naturally denuded. In summer their reddish tracks stand out against the dark green of the forest. The periodic return of the avalanche is an obstacle to the growth

Fig. 26—A tunnel to cross an avalanche in the Pénéon ravine on the road to La Bérarde, St. Christopher-en-Oisans (1600 m.). View in the spring of 1923: at the same date in 1922 this avalanche covered all but a half meter of the telegraph post in the foreground. (Photograph by V. Hulin.)

of trees. An exceptional avalanche or a periodic avalanche turned out of its customary channel will, on the other hand, destroy existing trees. It literally plows up the forest it traverses, beating down the trees and grinding them into pulp. On March 3, 1923, an avalanche that had not descended since 1862 ravaged a forest of sixty-year-old trees in the ravine of Combe Longe on Allemont en Oisans (Fig. 21). The same day in the upper Bréda Valley on the western slope of Belledonne an avalanche that had not come down since 1831 plowed up trees 90 years old (Fig. 28).

It may, however, happen that an avalanche crosses a wood without causing any great damage (Fig. 9). Such is the case where the snow is light and wet, flowing in semiliquid fashion, and where the actions of compression and refreezing are slight. The snow then slips more or less easily between the trees. It may tilt over the trees or they may be broken off at the base or they may even be completely respected when the flow of snow is limited.

The Avalanche and Man

The movements of man in the mountains are liable to be curtailed by avalanches at two points—in the zones of departure and arrival respectively.

It is at the starting point that most of the accidents to alpinists take place,[37] and these have been multiplied since the use of skis has permitted access to the high mountain in winter. In the zone of arrest the chief damage lies in the obstruction of routes of communication. Innumerable examples have been described in the literature, and it is unnecessary to cite new cases; we shall just mention the recent example of the avalanche of Roberts of March 3, 1923, which cut off the entire region of Oisans for 11 days (Figs. 25, 27).

Because of their relative slowness it is rare for ground avalanches to claim victims on the road; such avalanches can almost always be heard and avoided. However, instances are known. In February, 1924, a ground avalanche caught a train full of passengers in the station of Hieflau in Styria before coming to rest in the bed of the Enns. Because of its suddenness the powdery avalanche not infrequently claims victims along the road.

The clearing of a road encumbered by an avalanche always takes a long time because of the hardness of the snow and the compression and congealment that it undergoes. Generally a temporary road is established over the cone using either a trench (Fig. 27) or a tunnel (Fig. 26).

Since the development of hydro-electric power in the Alps a new sort of damage is to be apprehended from avalanches. Fallen masses of snow obstruct the intake channels as well as natural watercourses and for a longer time because of the geometrical section of the channels and their lesser gradient. Stoppage of water alone would not be so serious as the damage done to the installations, which may put the plants out of commission for several days (Fig. 28). A still more frequent accident is the breaking of the transmission wires: during the winter of 1922–1923 both in Savoy and Dauphiny a great number of producing plants were subjected to interruptions of from one to four days. All Lower Dauphiny had its electricity cut off by the avalanche of Roberts. These accidents coincide with the season when the hydro-electric industry is already hampered by scarcity of water.

Falling in winter or at the beginning of spring the avalanche naturally has no effect on agriculture except indirectly by the covering of ground with snow and by the purely local lowering of temperature already discussed. But in exceptional cases the fall of snow causes direct disasters to the human inhabitants of the mountains. Mountain villages avoid the usual tracks of avalanches. Accidents to settlements are only likely to occur under three conditions. In the first instance, a flow may be exceptionally long, reaching a point believed safe (Figs. 29, 30). In the second case, a flow may be diverted from its normal channel, this having been filled with snow by a preceding avalanche, as happened many times in 1922–1923 in Dauphiny. Or thirdly, a new avalanche may occur on a slope believed safe (see Figs. 13, 32, 33).

[37] On this subject there exists a special literature. See the works of Rutgers and Hess (the latter very complete) and the list of accidents periodically published by the various Alpine Clubs. There is a family resemblance between oral accounts of avalanches and fishing stories, and it is well to take them with a grain of salt.

FIG. 27

FIG. 28

FIG. 27—Temporary road across the avalanche of Roberts during the obstruction of the highroad and the railroad 30 meters below. Compare Fig. 25. The lumps of snow composing the avalanche are very distinct. Another smaller avalanche may be seen in the background on the other side of the valley. View four days after descent of avalanche. (Photograph by V. Hulin.)

FIG. 28—Intake channel of a hydro-electric plant obstructed by a ground avalanche loaded with earth and trees. Upper valley of the Bréda, Dauphiné, March, 1923. (Photograph by V. Hulin.)

FIG. 29

FIG. 30

FIG. 31

The hard snow carried by the avalanche is not contented with knocking over the houses, often it fills them, a circumstance that renders the work of rescue the more difficult. As in a mine accident, the exact spot where the victims are entombed must be known. This is difficult because, while they can hear perfectly the voices of the rescuers, they cannot make themselves heard. Coaz and Brocherel have recounted many tragic stories relating thereto.

STATISTICS OF AVALANCHES

Attention has been called to the dangers of avalanches as far back as records of the mountain country have been in existence. Fifteenth century texts, such as the chart of Henry VI of England on the Great St. Bernard Pass in 1422, have been described.[38] As a text of 1475 shows, the cutting of the first Alpine tunnel, that of the pass of Traversette at the end of the fifteenth century, was undertaken to afford protection from avalanches. I have recently found still more ancient texts relative to the avalanches of Dauphiny (Oisans) at the beginning of the fourteenth century.[39]

[38] Brocherel, *op. cit.*; Coaz, Die Lawinen.

[39] See some recent texts in Étienne Clouzot; L'enneigement dans le Queyras aux XVII[e] et XVIII[e] siècles, *La Géographie*, Vol. 31, 1916–17, pp. 252–260.

FIGS. 29 and 30—A house of Allemont, Oisans, that narrowly escaped destruction by the avalanche of Combe-Gibert, March 3, 1923. Figure 29, view from above looking towards the snow-covered plain of the Eau d'Olle; Figure 30, a side view, shows the avalanche charged with earthy and woody débris. (Photographs by V. Hulin.)

FIG. 31—House at Brévières, Tarentaise, Savoie, overthrown and filled with snow, February 12, 1881. (Photograph by Allotte de la Fuye and Jager.)

Fairly complete lists for the last three centuries have been drawn up by Dr. Coaz for Switzerland and P. Mougin for France. Unfortunately Mougin's tables only deal with Savoy (Departments Savoie and Haute Savoie with Mont Blanc). There is nothing for Dauphiny and the Pyrenees save some isolated articles. Similarly for Italy and Austria and other

FIG. 32

FIG. 33

FIGS. 32 and 33—A house of La Rivoire, Oisans, destroyed by the avalanche of March 3, 1923. Compare Figures 13, 19, and 20. Figure 32 was taken fifteen days after the descent. A cross marks the site of the house, and the arrow points to the spot whence Figure 33 was taken, six months later (Sept. 16).

mountain massifs as far as I know.[40] Here is a gap in geographical documentation waiting to be filled.

Statistics prove the truth of popular observation that avalanches tend to follow the same tracks. Sometimes they only descend two or three times a century; most commonly they are annual but then of rather limited dimensions; at variable intervals they may take on catastrophic propor-

[40] Brocherel, *op. cit.*; Hess, *op. cit.* See several notes by P. F. Denza in *Riv. Mensile Club Alpino Italiano*, Vols. 4 (1885) to 7 (1888), especially "Le valanghe dell' inverno 1888," Vol. 7, 1888, pp. 134–137.

tions. The avalanche Roberts, for example (Figs. 7*b* and 25), is annual; it generally comes to rest as a tongue in its ravine; but three times in 30 years it has reached the road and the river in the form of a big cone—in 1893,[41] in 1908, and in 1923.

Colored maps showing the tracks of annual avalanches have been prepared by Coaz for Switzerland and by Mougin for Savoy. In these maps the mountains are striped zebra-like. For Switzerland Coaz shows 9368

FIG. 34—Protective works against avalanches. Wooden fencing and reforestation below the tree line in Valais. (Photograph by J. Brocherel.)

tracks; Mougin 1361 for Savoy. Dauphiny would show at least as many. These figures include only the exceptional avalanches that descend into and devastate the inhabited zone, and the number would be infinitely greater if inclusion were made of the little avalanches so frequent on the high mountains above the tree line. On the map, Figure 7, I have attempted to show the two types of occurrence for a valley of Oisans in the spring of 1923.

The most terrible catastrophes of which history makes mention have occurred in the Swiss Alps. That of Louèche in Valais in 1719 wiped out the town, killing 60 persons; that of Obergestelen in 1720 destroyed 120 houses and killed 80 persons and 400 head of cattle; that of Saas in Grisons in 1689 wiped out place and people. In Italy the greatest catastrophes were those of 1885: in Exilles the avalanche of Deveis destroyed 16 houses and buried 62 persons, of whom 35 died; that of Frassino in the Val Varsita

[41] Pierre Lory: L'avalanche de Livet, *Trav. Lab. Géol. Univ. Grenoble*, Vol. 3, 1893, p. 283.

FIG. 35

FIG. 36

FIGS. 35 and 36—Protective works against avalanches. The use of stone fencing above the tree line. Figure 35 at Chantelouvre, Dauphiné; Figure 36 in Valjonffrey, Dauphiné. (Photographs by V. Hulin.)

killed 70 persons. In 1888 great new avalanches accounted for 145 victims in the Italian Alps.

I have elsewhere described the catastrophes of 1447 and 1450 at Ornon and Venosc in the French Alps, the first of which razed the hamlet of Poutuire and killed 14 persons, the second killing 5 persons and 75 head of cattle. In 1681 at Abrier in Queyras 57 houses were demolished and 11 persons were killed. Mougin's statistics record avalanches of two successive winters at La Giettaz at the foot of the pass of Aravis in 1843 and 1844; the first engulfed 8 houses and killed 14 persons; the second engulfed 8 more houses and 13 persons, of whom 6 died. On February 12, 1881, 14 houses were destroyed at Brévières, 37 persons being involved, of whom 9 succumbed. Reference has already been made to the casualties of 1923.

Protection against Avalanches

Such figures go to show that money expended in works of protection against avalanches is well spent. Study of works of this nature has been pushed far by the Forest Service of Switzerland since the middle of the eighteenth century and by that of France since the beginning of the nineteenth.[42] Protective works can be divided into two classes, which, following medical terminology, I term "preventive" and "curative." The latter consist in devices to restrict the destructive power of avalanches and includes the building of strong masonry walls in the shape of plowshares. In Switzerland artificial channels in stonework have been built to carry off the torrent of snow as for a too turbulent torrent of water. This method, however, seems to me inefficient because of the disproportion between the cost of erection and its eventual usefulness where an enormous volume of snow has to be contended with.

Preventive methods aim at prohibiting formation of the avalanche, that is at retaining the snow on the high slopes. For this wooden or stone fences, according to proximity and cost of material, have been commonly employed: however, I would suggest substitution in the latter cases of a more continuous metal trellis work (Fig. 35). The Forest Service has long advocated reforestation of the high slopes wherever feasible. It is not a new idea. Some among the oldest texts that I have found on avalanches in Dauphiny (fourteenth century) relate to forest administration and mention avalanches as one of the reasons for afforestation. Now avalanches may start from above or below the tree line. According to Mougin's figures about two-thirds of the ground avalanches and about half of the other avalanches start below tree line. This gives a theoretical measure of efficiency to be expected from afforestation as a means of suppression of avalanches. Reforestation is most often combined with a system of fences, at least at the beginning for the protection of the young growth (Fig. 34).

[42] Details in the works cited, Coaz and Hulin. More recent details and bibliography in the study of P. Mougin, Les avalanches en Savoie. Photographs in the article by Brocherel, *op. cit.* See also André Allix: Peut-on prévoir et empecher les avalanches? *Le Petit Dauphinois*, Grenoble, May 28, 1924.

Beyond the starting point it is of course obvious that no forest will stop an avalanche.

Prediction of Avalanches

Contrariwise to the question of protection little has been done towards prediction of avalanches.[43] In the first instance it must be pointed out that there can be no thought of forecasting the precise moment of release of an avalanche. The only observers qualified to speak on this matter, alpinists and ski runners, have all been impressed by the suddenness of the occurrence. To the observations of my predecessors I will add only two personal experiences; one on skis in Vercors on February 2, 1913; the other in Oisans on April 29, 1919. The most skillful cannot escape.[44] We may also refer to Mallory's experience on Mt. Everest, June 7, 1922, when his party was overwhelmed and seven porters killed:[45] "We were startled by an ominous sound, sharp, arresting, violent, and yet somehow soft like an explosion of untamped gunpowder. I had never before on a mountainside heard such a sound; but all of us, I imagine, knew instinctively what it meant, as though we had been accustomed to hear it every day of our lives. In a moment I observed the surface of the snow broken and puckered where it had been even for a few yards to the right of me. . . And then I began to move slowly downwards, inevitably carried on the whole moving surface by a force I was utterly powerless to resist."

Yet the native mountaineer is distinguished from the city-bred amateur by a certain instinct in regard to the occurrence of avalanches. The great majority of accidents of this kind happen to parties unaccompanied by a guide. Chamois hunters and professional guides are rarely caught. But it is impossible to give any rules about the release of avalanches, and the only advice of experts is that of Dr. Hoek: "Prudence, prudence, prudence: keep the rope in the knapsack, and distances well spaced."[46] Since the observations of Dr. Coaz many others have described the trifling causes that may start an avalanche; besides the passage of a party of individuals, a slight shaking of the ground, the sounding of a distant train, bells of the flocks, cries or shouts of passers-by. A wonderful observer of alpine nature, the late David Martin, himself a mountain peasant, tells how the children of Valgaudemar amuse themselves in winter by provoking miniature avalanches that they may slide down on them.[47]

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[43] André Allix: Sur la prévision des avalanches, *Comptes Rendus de l'Acad. des Sci.* [*de Paris*], Vol. 178, 1924, pp. 1831–1833.

[44] Among the many descriptions of this kind of accident I would mention those of A. de Quervain, *op. cit.*; J. I. Clark: An Avalanche Experience on Ben Achalladar, *Scottish Mountaineering Club Journ.*, Vol. 10, 1908–09, pp. 346–348.

[45] C. G. Bruce and Others: The Assault on Mount Everest, 1922, London, 1923, p. 282. See also André Allix: Les enseignments du Mont Everest, *Rev. de Géogr. Alpine*, Vol. 12, 1924, pp. 99–128; references on pp. 122 and 127.

[46] Use of the rope, invaluable on the glacier, is here extremely dangerous. Mrs. Clark (*op. cit.*) has described this in a fatal experience. The necessity of keeping far apart explains itself; one might further add the advice of following in separate tracks instead of Indian file, in order to avoid cutting the snow: as we have seen, it is the notch of the track which is the chief cause of the sliding of the snow board.

[47] *Le Courrier des Alpes*, Grenoble, March 17, 1904; information supplied by P. Lory.

Several avalanches may start almost simultaneously from the same point. Charles Rabot mentions an example that happened on February 4, 1897, on the Little St. Bernard, when the provisioning convoy of a military post was struck in succession by two death-dealing avalanches. Maurice Paillon, at the same period, saw avalanches succeed each other without interruption for 36 hours in the valley of Vénéon in Oisans with a roar comparable to that of a train in a tunnel.

There are, however, critical periods during which avalanches are particularly to be feared. At such time the snow is in a position that I have called subequilibrium (*sous-équilibre*),[48] analogous to what physicists know as the state of subliquefaction below the point of solidification. One knows that in this case solidification of the liquid may be effected by the introduction of some exciting factor, small though it be in itself. In the state of subequilibrium the snow is not merely in unstable equilibrium, but in an equilibrium already broken theoretically. In this state a slight exciting factor will make it begin to slide. Thus a most insignificant cause may give rise to a result as formidable as the avalanche.

Now in the matter of prediction of avalanches the most one can hope to obtain is the determination of this state of subequilibrium indicating the liability to accidents at critical periods. The immediate causes of release will always escape prevision; one can only avoid those provoked by human agency at critical periods.

There are two ways of determining the critical periods. The first, purely theoretical, is founded on the state of the snow and the application of certain mathematical formulae. Its application, however, is impracticable for lack of sufficient competent observers permanently located in the high mountain regions. The second method, which I advocate, is purely empirical. It consists in determining for a sufficient number of years the meteorological characteristics of the periods that precede the starting of avalanches by means of daily observations taken at average altitudes in all the mountain regions. In 8 or 10 years one would be in possession of "probability" tables likely to be of great service.

Figure 37 furnishes examples of observations of this nature applied to the French Alps. Graph *a* shows, contrary to a widely held opinion, that it is not the quantity of snow alone which provokes avalanches. At Bourg d'Oisans in 1922–1923, the place and period to which they refer, there fell hardly more than the average of snow. But this snow was distributed in a special fashion. In December the quantity was exceptional and alone would explain the occurrence of avalanches; in February, when it was less than the average, other causes must have been in operation.

Graph *b* is simply the juxtaposition on the same diagram of data furnished by Mougin for regions of Savoy between 500 and 1000 meters in altitude. It is surprising that he did not himself think of bringing together the sets of observations and drawing conclusions therefrom. The maximum

[48] *Rev. de Géogr. Alpine*, Vol. 11, 1923, p. 803.

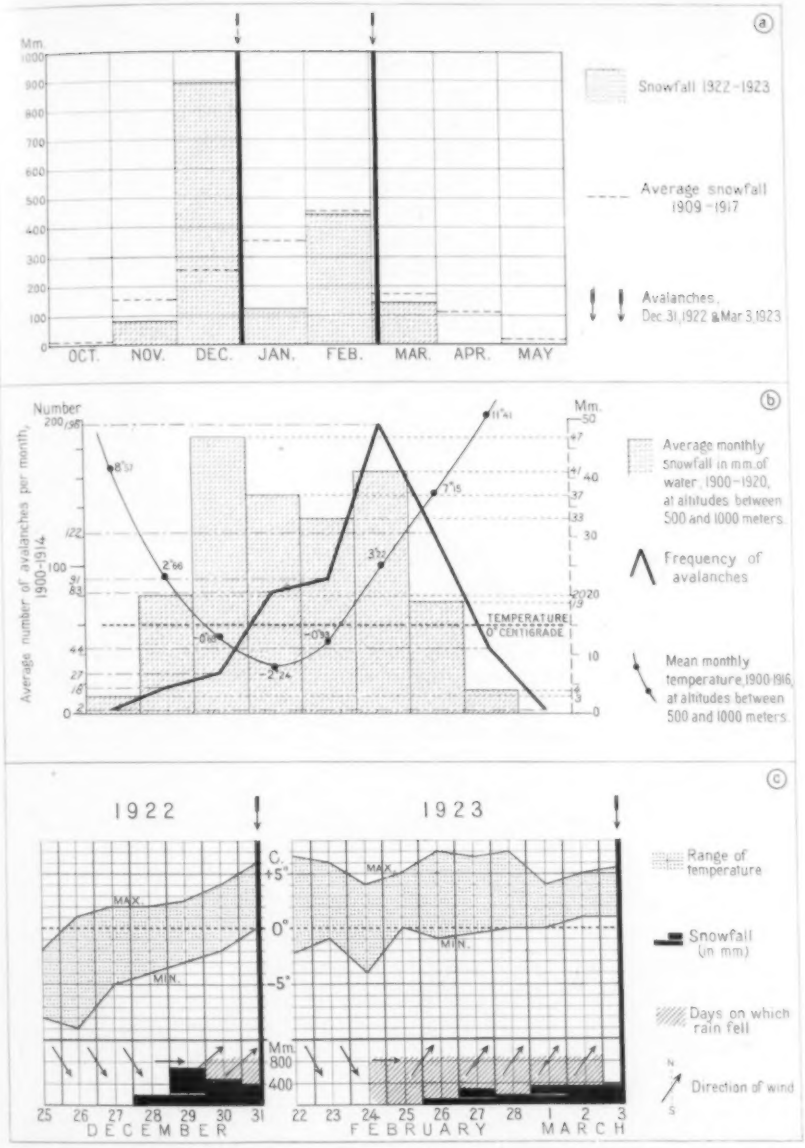

FIG. 37—Graphs illustrating researches on the prevision of avalanches (*Comptes Rendus de l'Acad. des Sci.*, 1924). Graph *a* shows the snowfall of the winter 1922–1923 compared with the average of eight years and relation with avalanches.

Graph *b* shows relations between the mean snowfall, mean monthly temperatures, and frequency of avalanches in Savoy.

Graph *c* shows meteorological conditions on the eve of the great avalanches of December 31, 1922, and March 3, 1923, in Oisans. (Data from Bourg d'Oisans.)

number of avalanches in March does not coincide with the maximum fall of snow in December: they become most frequent when the mean monthly temperature rises. To clinch the argument I have drawn Graph *c*, which visualizes the meteorological data for the critical periods of 1922–1923 in Oisans.[49] It appears that in the two cases the great avalanches start after a marked rise in temperature accompanied by fall of soft snow and a southwest wind. The cases studied are those of warm avalanches; work on cold avalanches remains to be begun. It will confirm the empirical observation that reduction in temperature here plays a part. It is probably this observation that Dufour echoes in a vague memorandum of 1878, the only work which, to my knowledge, has been specially devoted to the subject of prediction of avalanches.[50]

I do not claim to be the first to have studied the actual meteorological conditions of critical periods. Von Ficker has discussed the rôle of the föhn. Rütgers, notably, has given meteorological tables for certain Swiss avalanches, and he counsels ski runners always to furnish themselves with a thermometer. Maurice Paillon has given many observations in the periodicals of the French Alpine Club. But I emphasize the value of developing the method systematically upon strictly defined bases (pressure, winds, temperature, precipitation) to obtain in time true forecasting tables. Only probabilities for the detachment of avalanches at critical periods can be foreseen; the actual release rests on fortuitous causes. These phenomena, like meteorological storms, will always contain an unpredictable element. Furthermore, it should be noted that avalanches, like storms, are essentially local phenomena. The tables of Coaz and Mougin show this clearly enough. A year poor as a whole in great avalanches will yet show 7 or 8 or 10 considerable occurrences along the same valley, even on the territory of a single commune, whilst in neighboring regions they are few in number or limited to the usual small annual avalanches. This was instanced in the French Alps in 1923. In lower and central Oisans on March 3, 1923, between 4 and 5 o'clock in the morning there fell more than 100 avalanches, 10 of catastrophic dimensions. The same year in the Prealps and even in upper Oisans avalanches were below the average in number. Thus it is desirable to establish as extensive and dense a network of observations as possible for the forecasting tables.

With the hope of rendering practical service by the establishment of a method of prediction I leave the avalanche, a characteristic phenomena of the mountain, an occurrence that has been known and dreaded since man inhabited the mountain, and one which must be classed among the most powerful forces of nature.

[49] Allix, Les avalanches de 1922–1923 en Dauphiné, *Rev. de Géogr. Alpine*, Vol. 11, 1923, p. 526.

[50] C. Dufour: Sur la chute des avalanches, *Comptes Rendus de l'Acad. des Sci.* [*de Paris*], Vol. 87, 1878, p. 307.

NATURAL REGIONS OF CZECHOSLOVAKIA

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Czechoslovakia occupies a comparatively small area—it is not much larger than the state of New York—but therein is displayed the greatest variety of landscape. Side by side lie plains and mountains of various types; primeval forests and mining and manufacturing centers; rich plowland and high mountain pasture; mushroom towns of today and ancient cities now preoccupied with dreams of bygone glories.[1] This manifoldness, this changing of aspect almost at every step is a characteristic feature of the country. Another distinguishing feature is bound up with its situation.

For good reasons the Czechoslovakian republic has been called the heart of Europe. Though as regards area the center of Europe lies somewhat farther to the northeast, the center of population is approximately in the border region between Bohemia and Moravia. Czechoslovakia is situated on the threshold between the densely populated west and the sparsely inhabited east. This question of situation is of such fundamental importance that we shall examine it first.

Anterior Europe, as we may term that part of the European mainland west of a line running from the mouth of the Vistula (Weichsel) to that of the Danube, is crossed by two belts of mountains. From the Ardennes to the Bohemian massif we find an interrupted row of irregularly shaped fault-block mountains, remnants of a once continuous peneplain. From the Gulf of Genoa a great mountain arc, comprised by Alps and Carpathians, runs roughly northeast and eastwards. Where the Danube cuts across the arc it truncates obliquely the row of fault-block mountains. Between the two mountain systems, as well as north of the fault-block mountains and within the Alpino-Carpathian arc, lowlands border the foot of the highlands. The central forelands of the Alpine system and the German lowlands of the great European plain merge into each other where the fault-block series discontinues. The central lowland belongs to the Danube basin and thus makes connection with the southern, Pannonian lowlands. Now the meridional axis of Czechoslovakia lies just in the central lowland, between the Bohemian massif and the Carpathian section of the arc which here projects northward—that is where one barrier gives out and the other is pierced in a structurally weak (faulted and less elevated) spot by the Danube. In other words, Czechoslovakia is situated where the European

[1] For general accounts of the Czechoslovakian state and its people see Emmanuel de Martonne: L'État tchécoslovaque, *Ann. de Géogr.*, Vol. 29, 1920, pp. 161–181; M. S. Stanoyevich: Czecho-Slovakia and Its People, *Geogr. Rev.*, Vol. 8, 1919, pp. 31–36.

FIG. 1—Relief and regions of Czechoslovakia. The relief map is a photograph of a model with the addition of place names. Numbers on the regional map have reference thus: 1, border mountains (crystalline) of the Bohemian massif; 2, basins (Permo carboniferous and Cainzoic) of repeated down-faulting and weak rocks; 3, Tertiary volcanic regions; 4, Cretaceous table-land; 5, central and Bohemo-Moravian peneplain with chief monadnocks; 6, Flysch zone; 7, first Carpathian massif zone; 8, second massif zone; 9, third massif zone. Scale of the regional map 1: 7,000,000.

continental divide crosses a continuous lowland tract; and it thus is the natural center of through traffic in Europe.

The Fundamental Regional Division

The Bohemian massif to the west, the Carpathian ranges to the east of the meridional lowland belt are the two main subdivisions of Czechoslovakia. The first is the basin of the Vltava-Labe, the upper Elbe with its chief tributary, the Moldau. The Carpathian ranges and the lowlands to the west and south of them pertain with but insignificant exceptions to the Danubian system. Added to this hydrographic distinction is difference in structure and morphological development.

In the Bohemian massif the trend of the relief is almost entirely due to faulting and warping. In the northeast and southwest a northwest-southeast trend prevails, the two other sides being characterized by dislocations at right angles, giving a northeast-southwest trend. Upon the whole, these disturbances have resulted in an uplift of the border regions, hence the well-defined quadrilateral basin of Bohemia.

The rocks of the massif are on the whole resistant. Weak rocks are restricted to structural basins of a local character, and here the rivers have excavated broad lowlands, often bordered by fault scarps and flexures. Otherwise even the main rivers have barely reached the mature stage. Their present valleys, bordered by several sets of terraces, are sunk deeply into an uplifted peneplain, the uplift being more pronounced towards the borders (Fig. 2). Monadnocks of specially resistant rocks rise some 100 to 200 meters above the peneplain. They either form long ridges, following the strike of folded rocks, or are circular in arrangement, representing the metamorphosed rim of laccolithic intrusions.

In the Carpathian region, on the other hand, a zonal arrangement prevails both as regards structure and distribution of the various kinds of rocks. The outer zone is represented by the sandstones and slaty marls of the so-called Flysch. Within may be distinguished three zones of massifs, separated from the Flysch and from one another by strings of basins. The crystalline core of each massif is more or less mantled by limestones (Mesozoic), giving rise to karstic phenomena. In the south these massifs are partly covered by young volcanoes. Farther east the zone of massifs disappears, and a strip of lowland separates the Flysch mountains from a volcanic range.

While we contrast the faulted structure of the Bohemian massif with the young folded structure of the Carpathians, it must not be overlooked that even in the Carpathian Mountains the existing land forms are dependent primarily on uplift and faulting and not on the previous folding, young though it is, geologically speaking. Whether the area was ever peneplaned as a whole is still open to question. Yet unmistakably old land forms, traces of a far more advanced cycle of erosion, are to be found on the summit

level of the mountains. The rivers also are antecedent to the down-faulting of the intramontane basins. In young valleys, along which series of rock terraces at high levels may be traced, the rivers cross the barriers not only between two neighboring basins but even the massifs between outer and inner basins.

Another distinction due to the different stage of the physiographic cycle in the two regions rests in the difference of elevation. The central portion of the Bohemian peneplain lies at an elevation of approximately 500 meters with monadnocks rising 300 meters above it, the valley bottoms being only some 100 to 200 meters above sea level. Towards the sides of the Bohemian square the peneplain is warped up, reaching altitudes of 1000 to 1300 meters in the frontier mountains: it is only towards the southeast that this warping is less marked, the border along the Moravian corridor seldom exceeding 600 meters above sea level. In the Carpathians orogenic forces are far more in evidence. The elevation at which traces of the old land forms may be found often exceeds 2000 meters, the Gerlach pinnacle in the High Tatra rising to 2663 meters. This elevation is due to later crustal movements and does not represent the original elevation at which the land forms in question were developed, for until almost recent geological times the Carpathians were islands and peninsulas of seas and lakes in which sedimentation was in progress and round which may be traced shore-line terraces up to 500 meters and more above the present sea level.

The present land forms of both the Bohemian massif and the Carpathians were initiated by faulting and uplift, after the formation of a peneplain in the west, of subdued land forms in the east. But in the east the uplift was stronger, and the structure produced by folding is not yet obliterated by the younger fault structure.

Influence on Human Life

Human life reflects these conditions. The west is a region of flourishing manufacture. Large towns developed in the basins, the soft rocks of which contain rich resources of coal and lignite. Sheltered from the cold northern and rainy western winds they have a warm dry climate, yet with sufficient rainfall to permit the growing of cereals and beets. On a great thoroughfare from west to east, this section of Czechoslovakia gravitates towards the Atlantic. From early days it has been one of the most advanced centers of western civilization. Of the primitive landscape but little has survived. Fields of corn crops, sugar beets, cabbages, and potatoes have supplanted the former grassy steppes of the lowlands, the former woods of the mountains. Only the steep sides of young valleys and fault-line scarps are still forested to a considerable extent. The average density of population is 128 per square kilometer.

The Carpathians offered their early inhabitants shelter against the warlike, once nomadic, peoples of the Pannonian steppes. Only the intra-

FIG. 2

FIG. 3

FIG. 2—The Vltava (Moldau) south of Prague. An incised valley characteristic of the Bohemian massif; the peneplain in the background. (Photograph by Professor Radim Kettner.)

FIG. 3—In the Krkňose (Giant Mountains), the uplifted peneplain of the northeastern border of Bohemia. The lake-filled cirque of the Malý rybník (small fishpond) in the foreground. (Photograph by Professor Vitásek.)

montane basins are habitable. Here people cluster into small towns and large villages. Here, up to altitudes of sometimes more than 800 meters, arable soil is to be found, though there is always the threat of inundation when the snow melts in the mountains and torrents descend from their narrow ravines onto the level bottom of the basins. Lumbering is one of the chief occupations, and sheep raising rules life on the mountain pastures above the limit of forests, that is at an elevation of from 1300 to 1400 meters. The average population density of the whole region is but 57.

The influence of the orographic features on the development of communications is clearly exhibited. The roads of the Bohemian basin have been centered practically since prehistoric times on the site of Prague, where most of the larger rivers converge, though the former roads avoided the narrow deeply incised valleys, reaching the high-level plain by mounting the more gently inclined slopes of meander spurs.[2] The railroads prefer the valley bottoms, crossing the spurs by tunnels and using the alluvial flats developed now on the right, now on the left bank of the river. Therefore with the development of railroads a valleyward movement of the population set in. This applies especially to the valley of the Beroun, where limestone quarries opened in the folded Devonian limestones and the establishment of huge cement works created populous settlements.

In the Carpathian Mountains there exists no such natural center of communication. The main lines of traffic branch out from the Moravian corridor and cut through the Flysch belt by following transverse valleys. There valleys are always threatened by landslides; for the slopes are still being undercut by erosion, and the lithological nature of the formation—alternation of clays and sandstones—favors the tendency to slide. Within the Carpathian arc also the railroads follow the course of the rivers, passing from one basin to the next. Each small basin has its own center, all of them growing under the influence of the railroads, but no one showing signs of becoming all-important for the whole region.

The Bohemian Massif[3]

Northwestern Bohemia may be described as a broad arch, the keystone of which was down-faulted. The up-warped peneplain slopes gently towards the interior of Bohemia to the Cisařský Les (Imperial Forest) and towards Saxony in the Krušné Hory (Ore Mountains), but both these mountains turn a steep slope towards each other, at higher levels representing a much dissected fault scarp, farther down a young, nearly undissected fault-line scarp. These two features of the slopes are of different morphological age, but they may be due to the same faulting; or the mor-

[2] For details of the site of Prague see the author's paper, "Prague: A Geographical Sketch of the Town." *Geografiska Annaler*, Vol. 2, 1920, pp. 67–79.

[3] See also the author's paper "Les régions morphologiques du massif bohémien," *Ann. de Géogr.*, Vol. 32, 1923, pp. 41–57.

FIG. 4

FIG. 5

FIG. 4—Český Krumlov, an old town on the Vltava, in the spurs of the Šumava (Bohemian Forest).

FIG. 5—The Hrubá Skála (rough rocks) near Tumov in northern Bohemia. Topographic forms in the sandstone (Cretaceous) region of the Sudetic foothills. In the background the basaltic neck and crowning ruins of Trosky.

phologically young, lower part of the slopes may even be the geologically older one. For with the down-faulting sedimentation set in all over the down-faulted trough of the Ohře (Eger) basin, a thick mantle of sediments protecting the lower parts of the slopes against denudation until a new regional uplift revived river erosion.

Volcanic eruptions went hand in hand with the orogenic movements; the Domed Mountains (Středohoří) on both sides of the Labe, now base-leveled and faulted, and the Mountains of Doupov, crossed by the Ohře in a picturesque valley below Karlovy Vary (Carlsbad), are the largest of the volcanic remnants of Northwestern Bohemia. The last phenomena of volcanic activity still exist in the form of the numerous mineral and thermal springs, of which those of Karlovy Vary (Carlsbad) are the best known.

As the name "Ore Mountains" implies, the region is rich in minerals, ores of silver, copper, tungsten, etc., occurring in the contact zone between the crystalline schists and the granitic laccolites. For long the chief industry of the region was mining. At a later period, when the chief lodes were exhausted and mining no longer paid, a state of overpopulation obtained in the mountain region. Home industries were developed, poorly paid though these are, and remarkable skill in the making of all kinds of laces, wooden toys, and musical instruments has been acquired. There also set in a movement of migration downward into the basin of the Ohře, where lignites and fine china clay have given rise to a flourishing ceramic industry. More recently mining in the mountains has been revived, notably with the discovery at Jáchymov of pitchblende rich in uranium.

Northeastern Bohemia is the region of the Sudetic ranges. Here, too, the peneplain was warped up; but the keystone of the geanticline here still represents the highest part, facing with steep fault scarps the interior of Bohemia as well as the Silesian plain. The Sudetic Mountains might be described as more or less trunk-shaped. They are crossed by longitudinal and transverse faults, along which the blocks were moved differentially. The dominant block is that of the Krkonoše (Goat's Ridge, sometimes also called the Giant Mountains), rising in the Sněžka (Snow Dome, though rather pinnacled in shape) to 1603 meters. During the Ice Age this part of the Sudetic Mountains suffered glaciation of the Norwegian type; and the level, moor-covered fjeld presents a marked contrast to the steep sides of the cirques and the overdeepened valleys below (Fig. 3).

For man these mountains had little to offer. It is only in the valleys that one finds industries developed, linen weaving and paper making, using for the manufacturing processes the clear waters of the mountain streams as well as power from the rapids.

Southwestern Bohemia is the land of the Šumava (Bohemian Forest). These mountains may be considered to be residuals surviving from the former watershed of the great Bohemian peneplain, yet at the same time their summit level suggests the existence of an older peneplain, sloping

down towards the northeast. The central Bohemian monadnocks of the Brdy seem to be capped by this old peneplain, and near Prague it is seen to dip below the denuded edge of unfolded, almost undisturbed Cretaceous beds. The Bohemian Forest is the largest wooded area of Bohemia; and much wood is rafted down on the Vltava (Moldau), which here has its source.

Like the Bohemian Forest, the Bohemo-Moravian border region in the southeast is one of the least populated parts of Bohemia, the average density falling to 30. The general altitude does not exceed 600 meters, but the soil, derived from crystalline schists, is poor, the region exposed—it is called, though with much exaggeration, the "Bohemian Siberia." It offers no difficulties to transit and is crossed by numerous lines of traffic but by no important one such as might possibly stimulate the growth of towns along it.

The largest town of southern Bohemia, Budějovice (Budweis), is situated in the angle between the northwestward-trending Šumava and the northeastward-trending Bohemo-Moravian border regions, in a small downfaulted basin. Its origin as a prehistoric site may be traced to the impermeable clays that permitted the construction of fishponds.

The center of Bohemia is the pivot of the region, whether regarded geologically, economically, or historically. West of Prague coal is mined in the districts of Kladno and Plzeň (Pilsen). Rich iron ores, limestones, kaolin, and various brick clays occur in the immediate vicinity; hence the coal basins represent one of the chief manufacturing centers of Czechoslovakia. North of Prague we enter the region covered by Cretaceous rocks but slightly disturbed. On the border of the old lands, represented by the crystalline rocks of the Sudetic Mountains, sandstones dominate, often rising in weird shapes and covered by heath and dark pine forests. Here in the region of woods and arenaceous quartz lies the chief center of the celebrated Bohemian glass industry. Farther south fertile marls prevail or a superficial covering of loess. These lowlands along the Labe north of Prague are the Bohemian paradise, where wheat and sugar beet, the famous Bohemian barley and hop, the vine, and other fruits thrive. Manufacturing is here connected with agriculture, which not only furnishes the raw material but also the necessary labor. When the harvest is over, the season for the factories begins, providing work for the winter months. Truly a paradise, where work in the open air and in the factories alternates, giving opportunity for acquisition of health and wealth and without the drawbacks nearly always connected with manufacturing districts in the vicinity of a coal field.

The Moravian Corridor

In the east the Bohemian massif is bordered by the lowland belt of the Moravian corridor. In time almost recent geologically the corridor was occupied by a sea, which has left its mark not only in the sediments of the

lowlands but also in marine beaches and platforms of abrasion along the border of the massif as well as along that of the Carpathians. As the sea washed the shores of a peneplain in the west, in the east a land of dissected mountains, the two shore lines are rather dissimilar. In the west the old shore line runs almost straight, in the east the sea invaded the valleys in long narrow gulfs. Isolated hills rise above the lowland; they are the summits of down-faulted mountain ranges, once connecting the Alpine and Carpathian sections of the arc. Though isolated and of slight elevation, some 500 meters, they yet protect the southern part of the lowland against the cold northers, and here the same economic conditions prevail as in the central Bohemian plain. Farther to the north the climate is more severe, and stock raising assumes more importance. Then suddenly the scenery changes. Dark smoke clouds hang over the landscape, heaps of slag disfigure the ground, a hundred towering chimneys proclaim the entry into the manufacturing region of the Ostrava coal field, the chief coal district of Czechoslovakia, situated just on the frontier and forming the southern edge of the Upper Silesian coal field (Fig. 6). The Ostrava conurbation is far more populous than even the principal town of Moravia, Brno (Brünn).

Brno lies within the massif, where several rivers unite before crossing its border towards the lowland. Sheep farming on the mountain heights; small coal fields west of Brno which, lying in a narrow down-fault trough, escaped denudation; and the occurrence of various clays have made of Brno a manufacturing center, with a woollen manufacture celebrated from of old and a stove-manufacturing industry that sprang from the making of Dutch tiles. Though less important than Prague (676,476), Brno (221,422) excels it by far in the beauties of its surroundings. North of Brno lies the wonderland of the Moravian Karst with its stalactite caves in Devonian limestones; and in the east, beyond the lowland, the blue ridge of the Carpathians borders the horizon.

The Carpathian Arc

Within the Carpathian region of Czechoslovakia two main subdivisions may be distinguished. In the west is Slovakia, where small basins alternate with mountain groups. In the east is one large basin, the Marmaroš, where the upper Tisa gathers its waters, the center of Carpathian Ruthenia (Podkarpatská Rus). Between these two regions the Prešov-Košice (Eperies-Kassa) corridor runs northward to the Flysch range, where low gaps, only some 500 meters in elevation, act as gateways.

This Flysch zone, representing the northernmost or outer range, is the most continuous of all the Carpathian zones for it stretches far into Rumania. Permanent settlements are to be found in the valleys, the mountains being frequented only by woodmen and seminomadic shepherds. The same is the case with the massifs of Slovakia, composed of granites, crys-

FIG. 6

FIG. 7

FIG. 6—Vítkovice, a typical mushroom town in the mining and manufacturing region of Ostrava, on the Moravo-Silesian border.

FIG. 7—Kremnica, an old mining town in the volcanic mountains of southern Slovakia.

talline schists, and Mesozoic limestones, all intensely folded and fractured, rich in mineral and thermal waters, and not improbably far richer in ores than the comparatively few mines already opened would indicate. Where the mountains border on the basins numerous quarries have been opened, but traffic is still too poor to make quarrying pay farther in the interior. The loftiest of these massifs is that of the High Tatra (2663 meters), sculptured by Quaternary glaciers, with cirques occupied by small lakes overtowered by steep walls of dark red rock or wood-clad slopes of a deep green under a blue sky, and snow fields which vanish only late in the summer. One can well understand the brilliancy of colors displayed in the national paintings and embroideries and their perfect blending! No wonder that health resorts and tourist centers are being developed in these mountains which rival in their beauty the most renowned attractions of Switzerland.

The main river of this region is the Váh (Waag), a tributary of the Danube, which it joins in the great Slovakian plain on the southern border of the Carpathian Mountains. Where the Danube crosses the Carpathian arc the principal town of Slovakia, Bratislava (Pressburg), arose. With Komárno a little farther downstream it is the chief Czechoslovakian port on the Danube, and the contemplated construction of a waterway between the Labe (Elbe) and Danube would greatly increase its importance. The Slovakian plain is but a part of the huge Pannonian down-fault within the Carpathian arc. Economically it resembles the southern part of the Moravian corridor.

Northward along the rivers flowing down from the Carpathian Mountains the plain gradually peters out. On the Váh a narrow gap, where the hot springs of Trenčin have created a spa, leads from the plain to the first and most important of the intramontane basins, that of Žilina. This is a railway junction and a center of the main manufacturing industries characteristic of the Carpathians—wood working, pulp making, the working of wool, flax, pottery, glass, and iron, for which last-named industry the mines of the Slovakian Ore Mountains furnish the raw material. All the other materials are produced on the spot: coal has to be brought thither from Ostrava, but the white coal of the bordering mountains already furnishes a considerable part of the motive power.

Upstream of the Váh we pass through the basin of Turec to the great basin south of the High Tatra. By an imperceptible divide its western part, the basin of Liptov, where rise the headstreams of the Váh, is distinguished from the basin of Spiš where the Hernad, the chief tributary of the Tisa, and the Poprad, which crosses the Flysch mountains to join the Vistula, have their headwaters. Here likewise manufacturing is in progress together with farming and lumbering, and little ancient towns are to be found all along the former highroads, now deserted for the railroad. But it should be observed that these towns of Slovakia are in no way like American or western European towns. They are in fact more like large

FIG. 8

FIG. 9

FIG. 10

FIG. 8—A Slovakian village: the square before the church. Note the white or light tinting of the house walls and the characteristic overhanging roofs. (Photograph by Professor Vitásek.)

FIG. 9—Panorama of the High Tatra seen from the basin of Spiš. The contrast between the mountains and the flat-bottomed basin would be still sharper but for the waste cloaking the lower part of the fault scarp.

FIG. 10—A shepherd's hut, *salaš*, near the tree line in Carpathian Ruthenia. (Photograph by Professor Jiří Král.)

villages: only the central square has proper houses instead of huts, and these for the most part are but one-storied.

The valley of the Hron (Gran), the second large tributary of the Danube with a course parallel to that of the Váh, borders the Slovakian Ore Mountains to the north and separates them from the mountains of Štiavnica and Kremnica to the west. These volcanic mountains of Tertiary age give rise to rather broken and hummocky country with woods, pastures, small fields, orchards, and vine-clad southern slopes. A mountain railroad with numerous tunnels and lofty viaducts connects Štiavnica with Kremnica, lying picturesquely at the foot of the hill crowned by the station, the town reappearing at each curve of the train, winding up to cross the mountain barrier on its way to Turec. From ancient days gold and silver, together with copper, have been mined in this volcanic region, and the mint of Czechoslovakia was established at Kremnica.

The crystalline schists of the Ore Mountains of Slovakia contain iron, copper, and manganese; and in the small valleys in the heart of uninhabited, almost primeval, forests we come upon forges and rolling mills. Báňská Bystrica on the Hron may be said to be the economic center of this mining region, though situated on its northern border. In this town the mansions of the medieval mining masters with gates carrying armorial bearings give to the great central square its distinctive physiognomy.

East of the Tatra and the Ore Mountains the crystalline rocks disappear along the tectonic trough of the Hernad, where the Pannonian plain extends northward to the very edge of the Flysch zone. This corridor is the chief meridional highway of Slovakia; and larger towns, Košice (52,699 inhabitants) and Prešov (17,581), arose here, chiefly Jewish market centers. To the east the corridor of the Hernad is bordered by the Tertiary volcanic mountains of Prešov, in the andesites of which beautiful opals are mined. Here, too, mineral and hot springs are the last tokens of former volcanic activity.

In the Prešov district about the frontier between Slovakia and Carpathian Ruthenia three different regions may be distinguished. That of the Flysch zone is low in the west but rises towards the east in the Czornahora to over 2000 meters, the summits being sculptured by Quaternary glaciers. Whether of greater or lesser elevation these mountains are almost invariably covered by uninhabited woods. The poor soil and the severe climate—the region is unprotected to the north—allow only the cultivation of the more hardy crops, oats and potatoes, in the more sheltered valleys. Where the mountains rise above the upper tree line, at an elevation of about 1300 meters, isolated *salašes* are the temporary abodes of the seminomadic shepherds (Fig. 10).

A volcanic range, the Vihorlat Mountains, hugs the southern border of the Flysch zone in the west. Farther eastward the volcanic mountains trend to the southeast and, crossing the Tisa, continue as the Gutin Mountains of Rumania. Their vine-clad slopes separate the basin of the upper

Tisa, the Marmaroš, from the northern gulf of the Pannonian plain around Užhorod.

The Neogene sea entered the mountain-walled basin of the Marmaroš, and herein thick beds of rock salt were deposited. The salt resources of the Marmaroš seem to be inexhaustible, and they are the more precious as they are the only ones in Czechoslovakia. Chemical works are springing up in the vicinity of the mines; and, as the plain west of the Vihorlat Mountains is rich in lignites of excellent quality though still little worked, a center of chemical manufacturing will probably originate here in the far east of Czechoslovakia—a counterpart to that of Ústi-on-the-Labe (Aussig) in the west, where the northwest Bohemian lignite field reaches the trade route of the navigable Labe, providing cheap carriage for raw material often brought from a distance.

The valley of the upper Tisa lies in the axis of the basin. Though only some four kilometers broad, the valley is more than 70 kilometers in length; and, as it has fertile soil and a genial climate, we find here a strip of highly cultivated land. Its orchards, alternating with fields, offer a pleasing contrast to the Ruthenian steppes west of the Gutin Mountains. That part of the Pannonian plain is still sinking and at a quicker rate than the Tisa and its tributaries accumulate. Accordingly swamps, but recently drained, covered the entire region. It is a fertile but in no way a beautiful district—monotonous, level, yielding rich harvests, but unrelieved by tree or bush.

These are the varied features of Czechoslovakia. Regions of beauty and utility, great mountains and productive fields form the "vlast," as we call it, "the land that belongs to us."

AN ICE-ERODED FIORD

THE MODE OF ORIGIN OF LYNN CANAL, ALASKA*

By Lawrence Martin and Frank E. Williams

Lynn Canal-Chatham Strait is the longest and straightest and probably the most interesting, important, and picturesque of the many large fiords in southeastern Alaska. It extends in an almost direct line for 250 miles across the Coast Range of British Columbia and Alaska and the mountainous outlying islands. It is from one to five miles wide and has an extreme depth of 2900 feet. At the north it divides into Chilkat and Chilkoot Inlets. Within an area 350 miles long and having an average width of about 150 miles, extending from latitude 54° 40′ to 59° 30′ N. and from longitude 130° to 137° W., is a fiorded coast like that which continues southward with equal grandeur in British Columbia. It is one of the great fiord regions of the world, comparable in scale to the coasts of Norway, Greenland, New Zealand, and southwestern Chile.

The Lynn Canal-Chatham Strait fiord is in a mountain region where glacial erosion, stream erosion, change of level of the land, and faulting have all taken place. Its origin may, therefore, be thought to have involved: (1) ice erosion alone; (2) stream erosion chiefly, followed by sinking of the land; (3) stream erosion and glacial erosion, followed by submergence; (4) faulting as a major cause; (5) some combination of all four. It is the purpose of this paper to show that the fiord is due chiefly to glacial erosion and that stream erosion and faulting are of minor importance.

Many fiords of varying size join this straight waterway. Some of them are small tributary inlets, while others are wide passages nearly as deep as Lynn Canal-Chatham Strait. Among the former are Berners Bay, St. James Bay, Tenakee Inlet, Tebenkof Bay, and many smaller indentations. Of the larger class are Glacier Bay-Icy Strait, Stephens Passage, Peril Strait, and Frederick Sound-Taku Inlet. Most of these are submarine troughs which were probably original tributaries to a preglacial valley on the site of the present Lynn Canal-Chatham Strait fiord.

* Various parts of this fiord have been discussed by Nordenskjöld, Davidson, Brooks, Gilbert, Spencer, the Wrights, Knopf, and others. Gilbert, especially, studied the effects of glaciation. The senior author of this paper has seen all of Lynn Canal, Chatham Strait, Frederick Sound, Stephens Passage, Icy Strait, Cross Sound, and Peril Strait, except a short stretch in Chatham Strait between Peril Strait and Frederick Sound. Most of these fiords he has traversed several times by daylight in connection with six trips to Alaska. He studied portions of Lynn Canal-Chatham Strait and its tributaries in detail, working on shore and from launches in 1905, 1911, and 1913. He visited Glacier Bay, Dundas Bay, Taylor Bay, and Excursion Inlet, north of Cross Sound-Icy Strait; localities at Flynn Cove south of Icy Strait on Chicagof Island; at Davidson Glacier, Skagway, and Tee Harbor on Lynn Canal; at Juneau and Treadwell gold mine on Gastineau Channel; near Taku and Norris Glaciers on Taku Inlet; and at Funter Bay and Killisnoo on Admiralty Island east of Chatham Strait. He sailed through these and other parts of this fiord system on steamships in 1904, 1909, and 1910, accompanied in the latter year by the junior author.

There are no tidal glaciers in the main fiord, but many small ice tongues lie on the steep slopes of Lynn Canal and its tributaries. East of Lynn Canal the large Mendenhall, Eagle, and Herbert Glaciers still terminate 100 to 400 feet above sea level. West of the fiord one moderate-sized glacier, the Davidson, ends almost at sea level. There are fifteen or twenty large ice tongues in the Glacier Bay tributary of Lynn Canal and four in Taku Inlet, most of those in the last two fiords entering tidewater. The evolution of drainage from preglacial through glacial to present conditions is shown in Figure 1.

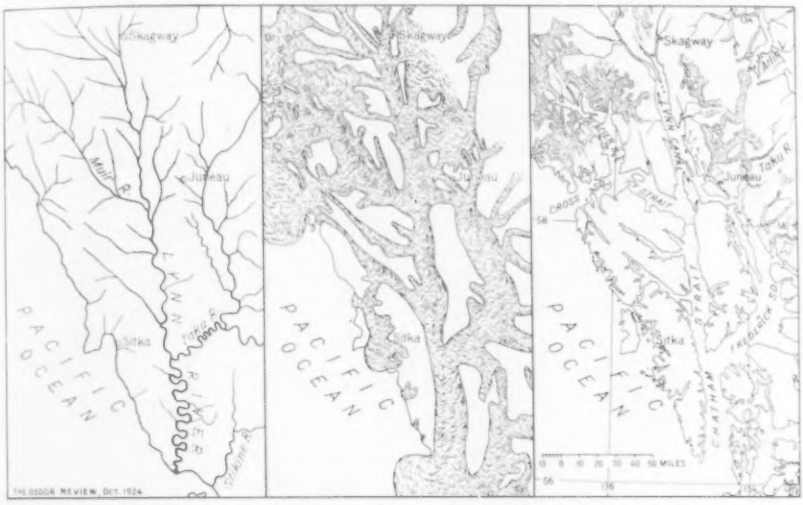

FIG. 1—Maps showing the evolution of the drainage of the Lynn Canal region: on the left, probable preglacial drainage; in the center, the more important glaciers at the flood stage; on the right, present fiords and glaciers.

CROSS SECTION OF THE FIORD

The slopes above and below sea level are essentially the same. The fiord has steep walls (Figs. 5, 9) and, in most places, a wide, almost flat bottom. In northern Lynn Canal the fiord walls rise 4000 to 6000 feet above sea level and, as the water is 900 to 2400 feet deep, the total relief represented in the cross section exceeds a mile at many points. In Chatham Strait the fiord walls are generally lower, although just north of Frederick Sound the relief is 5180 feet—from Table Mountain, 2438 feet, to the bottom of Chatham Strait, 2742 feet. The greater width makes the fiord cross section seem flatter toward the south. Indeed, to the average traveler the most imposing fiord scenery in Lynn Canal-Chatham Strait is at the north in Taiya Inlet, where the fiord is both steep-sided and narrow. This applies especially to the view as one sees it from a ship (Fig. 10). The prospect from any point on the fiord walls is everywhere impressive, as in the photograph

of a broad part of Lynn Canal (Fig. 9). The cross section is less a U-shape than that of a wide, flat pan with flaring sides. The fiord walls are not precipitous, for an angle greater than 45° is uncommon, while the average is probably much less than 30°.

A comparison of the fiord cross section with that of an ordinary, un-

FIG. 2—Photograph of relief map of Lynn Canal and Glacier Bay-Icy Strait, the two northern tributaries of the Chatham Strait fiord, showing glaciers existing in 1894 whose expanded ancestors carved out Lynn Canal-Chatham Strait (W. F. King, Canadian Boundary Survey). The numbers have reference thus: 1, Mt. Fairweather; 2, Lituya Bay; 3, Mt. Crillon; 4, Cape Spencer; 5, Taylor Bay; 6, Dundas Bay; 7, Berg Bay; 8, Pt. Gustavus; 9, Pt. Couverden; 10, Taku Inlet; 11, Pt. Bridget; 12, Pt. St. Mary; 13, Berners Bay; 14, Pyramid Harbor; 15, Pyramid I.; 16, Skagway; 17, White Pass; 18, Chilkoot Pass.

glaciated river valley converted into an arm of the sea by the sinking of the land brings out the salient features of each.

It may be seen by a study of maps of the same scale that the trough of Chatham Strait, Alaska, is much wider than that of Delaware Bay in the eastern United States, but their chief difference is not in size but in the slopes of the submarine valley walls (Fig. 13). The cross section of the Hudson north of New York, where it was modified by glaciation, is also

drawn for comparison. The slopes of the channel walls of Delaware Bay and Hudson River are so gentle that they cannot be shown without exaggerating the vertical scale. The submarine walls of Chatham Strait can easily be drawn to natural scale and show a steeper slope than those of Delaware Bay and Hudson River, although the vertical distances in the cross section of the latter have been multiplied by four. The wide, flat-bottomed, steep-sided troughs of the fiords, as contrasted with the nar-

FIG. 3

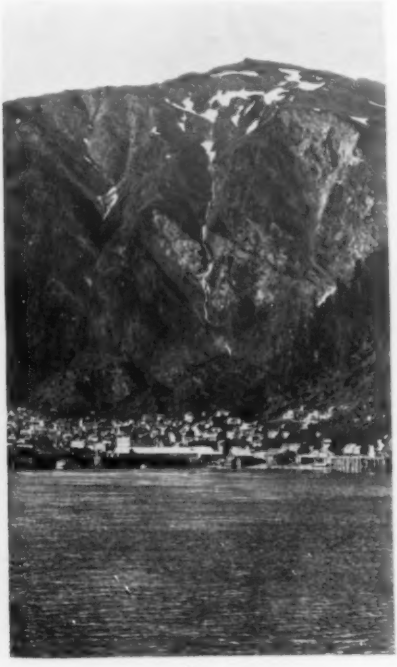

FIG. 4

FIG. 3—Juneau, the capital of Alaska. Juneau is on Gastineau Channel, one of the tributaries of Stephens Passage, a fiord confluent with Lynn Canal.

FIG. 4—The glacially oversteepened fiord wall of Gastineau Channel at Juneau.

rower river valleys with gentle slopes, show clearly the effects of profound glacial scouring and marginal trimming.

LONGITUDINAL SECTION OF THE FIORD

Above sea level the longitudinal section of the fiord is simple. Between valleys the spurs are sharply truncated. Uninterrupted views cover exceedingly long distances, as in most glaciated valleys (Fig. 18). The depth of the fiord is 1400 feet near the southern end of Taiya Inlet, 400 feet at the junction of Taiya and Chilkoot Inlets, 2900 feet off the northeast coast of

Baranof Island in Chatham Strait, 2100 feet east of Cape Ommaney, and 1000 to 1500 feet at the mouth of Chatham Strait in the Pacific Ocean. These depths of water show that there is not a gradual slope from the head of the fiord to the mouth but that there are alternations of deep basins and relatively shallow stretches. Figures 15 and 16, which represent the bottom of the main channel of the whole fiord, reveal numerous irregularities in the longitudinal profile. This shows remarkable contrast with the profile of a river; for irregularities of a few feet in the bottoms of stream courses are not uncommon, but differences of several hundred or a thousand feet or more are never found.

FIG. 5—The northern portion of the Lynn Canal fiord, showing the topography above sea level. Contour interval 500 feet. Reduced from Sheet III, Map of a portion of the Yukon District, Northwest Territory with the adjacent Northern Part of British Columbia, by G. M. Dawson, edit. of 1898.

TRIBUTARIES OF THE MAIN FIORD

Many tributaries having the same characteristics as Lynn Canal-Chatham Strait have been studied in connection with the problem of the main fiord. The largest tributary fiords are twelve in number. They may be identified upon various maps illustrating this article. Almost all of them show a depth of at least several hundred feet, and some are from 1500 to 1700 feet deep, Frederick Sound being the deepest. They are all remarkable for their straight and steep sides and for their flat bottoms. They range in size from Gastineau Channel, which is 17 miles long and 1½ miles wide, to Stephens Passage, which is 120 miles long and from 4 to 15 miles wide.

HANGING VALLEYS

Near Lynn Canal a great number of valley troughs terminate at different heights as hanging valleys. In many places there has been scarcely any stream erosion since the disappearance of the ice, and accordingly waterfalls are numerous. Some of the best and most picturesque of these hanging valleys are in Taiya Inlet near Skagway (Fig. 21) and in Glacier Bay (Fig. 20).

Soundings show many submarine hanging valleys also. The bottom of Skagway Harbor hangs between 200 and 300 feet above that of the main

fiord which terminates at Dyea. The bottom of St. James Bay hangs 800 feet above that of Lynn Canal. Irregularities in the bottom of the fiord render it difficult to determine the exact amount of discordance of Icy Strait, but it is clearly between 600 and 800 feet. The bottom of Frederick Sound hangs 1300 feet above that of Chatham Strait (Fig. 22). Freshwater Bay, Tenakee Inlet, and Hooniah Sound are discordant by amounts of 900 to 1100 feet. The floors of smaller tributary fiords hang at even greater elevations above the main fiord floor—the bottom of Hood Bay is 1400 feet above that of Chatham Strait, and the bottom of Funter Bay is 1700 feet above that of Lynn Canal. There are also secondary submarine hanging valleys, as in certain tributaries of Frederick Sound-Stephens Passage. In speaking of what he regards as the small amount of work accomplished by glacial erosion Knopf says: "It is therefore a problem of some interest why the troughs of the transverse tributaries, such as those of Berners, Eagle, and Mendenhall Rivers, are not hung up high above the bottom of Lynn Canal."[1] He seems to have overlooked the soundings, which show that Berners Bay does hang 300 feet above the bottom of Lynn Canal. Moreover, it will be necessary to know to what depth the Eagle and Mendenhall Rivers have deposited material in the fiord at their mouths before it can be stated that they meet the main channel with accordant junctions and are not hanging valleys in relation to the bottom of the fiord.

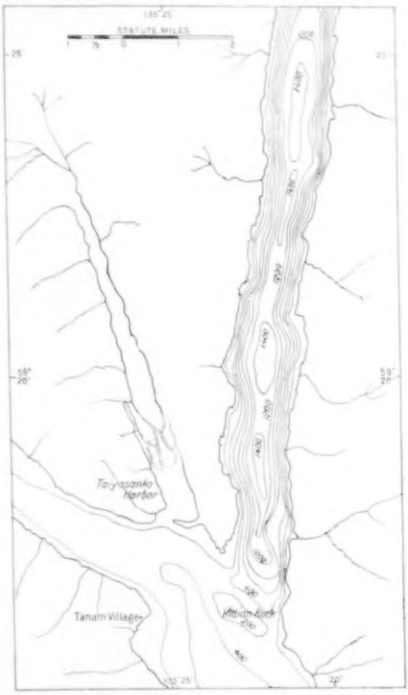

FIG. 6—Map of part of Taiya Inlet at the head of Lynn Canal, showing its outline and form to be entirely different from that of a drowned river valley like Chesapeake Bay (compare Fig. 13). Based upon Chart 8303, U. S. Coast and Geodetic Survey.

THE ORIGIN OF ISLANDS AND REEFS

There are a few islands in the northern half of Lynn Canal-Chatham Strait. Shelter Island, one of the largest, is about ten miles long. Several of the islands are more than 500 feet high, but none in this fiord reach a height of 1000 feet; while the fiord walls are four to six times as high. Some

[1] Adolph Knopf: The Eagle River Region, Southeastern Alaska, *U. S. Geol. Survey, Bull. 502*, 1912, pp. 12–13.

islands rise only a score of feet above sea level, and some reefs are awash; but the latter are rare. The wire-drag surveys show that the fiords of southeastern Alaska contain many submarine pinnacles that were not revealed by sounding. The reefs at the north end of Sentinel Island west of Eagle Glacier, where the steamship *Princess May* was wrecked in 1910

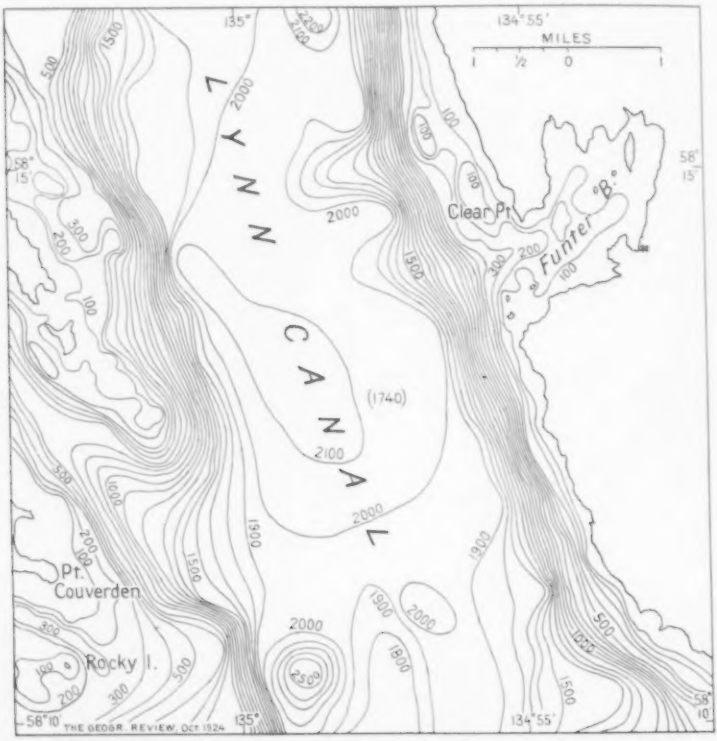

FIG. 7—Map of Lynn Canal near its junction with Glacier Bay-Icy Strait, showing the steep submarine wall of the fiord and its flat floor. Contour interval 100 feet. Based upon Chart 8302, U. S. Coast and Geodetic Survey.

and the *Princess Sophia* at a subsequent date, constitute a menace to navigation attributable to the differential glacial sculpture that has left these rare reefs and islands of resistant rock in the broader stretches of fiord. The southern half of the fiord is devoid of islands, with the exception of small ones near the shore. The soundings show few submarine knobs. Islands are absent where the fiord is narrow and deep and are more numerous in the broad, shallow stretches. This suggests that where the fiord is narrow the ice may have occupied one preglacial valley and that in some of the places where it is broad it filled parallel or converging valleys, overriding the minor divides. The ice wore down the divides as well as the valley bottom; but some of the eminences remained high enough to appear

FIG. 8

FIG. 9

FIG. 10

FIG. 8—Taiya Inlet at Skagway, showing the head of the Lynn Canal fiord. (Photograph by L. M. Prindle.)
FIG. 9—Lynn Canal at the junction of Chilkat and Chilkoot Inlets. Davidson Glacier on the left. (Photograph by N. J. Ogilvie.)
FIG. 10—The steep eastern wall of Lynn Canal, showing small glaciers along the fiord.

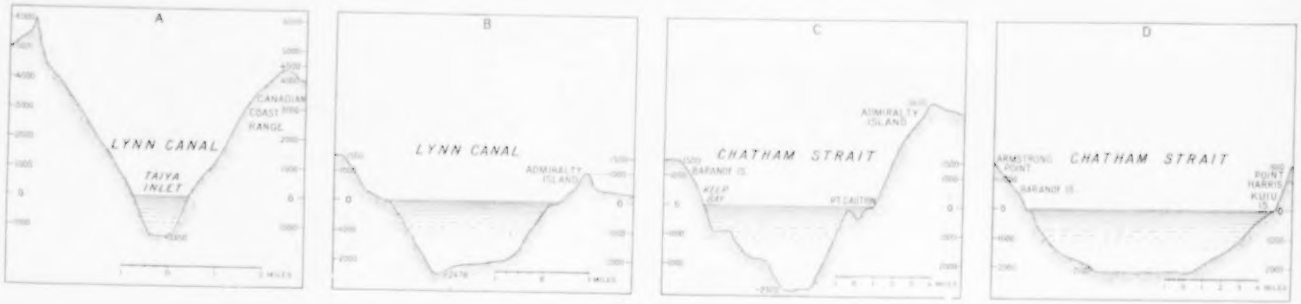

FIG. 11

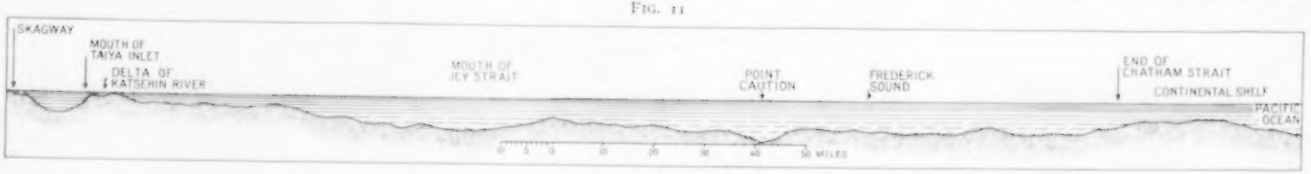

FIG. 12

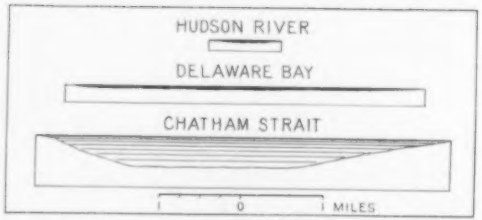

FIG. 13

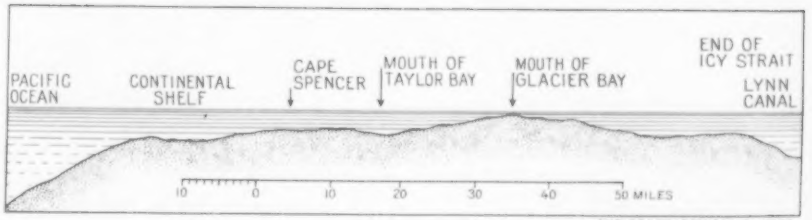

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FIG. 14

FIG. 11—Cross sections of Lynn Canal-Chatham Strait. A, just south of Skagway; B, 80 miles farther south near the mouth of Icy Strait; C, near Peril Strait at the deepest point in the fiord; D, near the mouth of the fiord, 10 miles from the Pacific Ocean.

FIG. 12—Longitudinal section of Lynn Canal-Chatham Strait, showing its basined character. Vertical scale about 16 times horizontal scale.

FIG. 13—Cross sections of Hudson River (above), Delaware Bay (middle), and Chatham Strait (below). The vertical scale of the two former is exaggerated four times; that of Chatham Strait is drawn to true scale.

FIG. 14—Profile through Icy Strait and Cross Sound, showing the submarine divide at the mouth of Glacier Bay. It is suggested that the connecting of these two preglacial river valleys is due to glacial erosion without sinking of the land. Vertical scale about 16 times horizontal scale.

above sea level at the time when the ice tongues melted away and glacial erosion ceased.

The slopes of the islands are about the same as those of the neighboring mainland—some quite steep, others rather gentle. The longer axes of the principal islands have, in general, the same trend as the coast of the mainland, which is more nearly northwest than the trend of the fiord and agrees with the strike of the rocks. Practically all the islands are in line with adjacent peninsulas, of which they are clearly cut-off portions. Their position and trend suggest a relationship to resistant rock and preglacial drainage. The presence of islands in a glaciated fiord is not remarkable, even if the rock were of the same resistance. Islands seem to have the same relation to ice currents that rock reefs bear to river currents.

The Mouth of the Fiord

The scattered Coast and Geodetic Survey soundings off the mouth of Chatham Strait show a wide submarine channel with relatively steep sides, extending from the fiord across the continental shelf. The fiord mouth, then, is not at the edge of the land but about 30 miles out at sea. This channel is 1000 to 1200 feet deep and between 15 and 20 miles wide. There are also excellent data to show the continuation of Cross Sound across the continental shelf. There is a definite, wide, steep-sided trough, about ten miles wide at Cape Spencer and nearly 30 miles wide and 1400 feet deep at the edge of the continental slope (Fig. 16). Such submarine channels as the two just mentioned might have been the result of: (1) ice tongues extending across the continental shelf and eroding below sea level, because the water was not deep enough for them to be afloat; (2) submerged stream valleys; (3) stream valleys that have been deepened and widened by glaciers and then submerged; (4) rift valleys made by faulting. The supposition that faulting is responsible for the channels requires a conception of a complicated fault system and a repetition of down-faulted valleys. At present no tidal glaciers in Alaska extend far beyond their confining walls into large bodies of water, but the ice tongues that filled these valleys at the maximum stage of glaciation were much larger and may have extended a short distance into the sea. The submarine channels that are definitely known to be due to stream erosion are either narrow gorges or very wide troughs with gentle slopes. There are submarine valleys off the mouths of many rivers along the eastern coast of North America. The submarine gorges of the Hudson and Delaware Rivers are, perhaps, the best known. The former is deeper than the Cross Sound and Chatham Strait channels but is much narrower. It averages less than two miles in width and nowhere exceeds four miles.[2]

The wide, steep-sided, submarine channels of southeastern Alaska, their position off fiords known to be glaciated, their width as compared with the

[2] J. W. Spencer: The Submarine Great Canyon of the Hudson River. *Amer. Journ. of Sci.*, Ser. 4, Vol. 19, 1905, pp. 1–15.

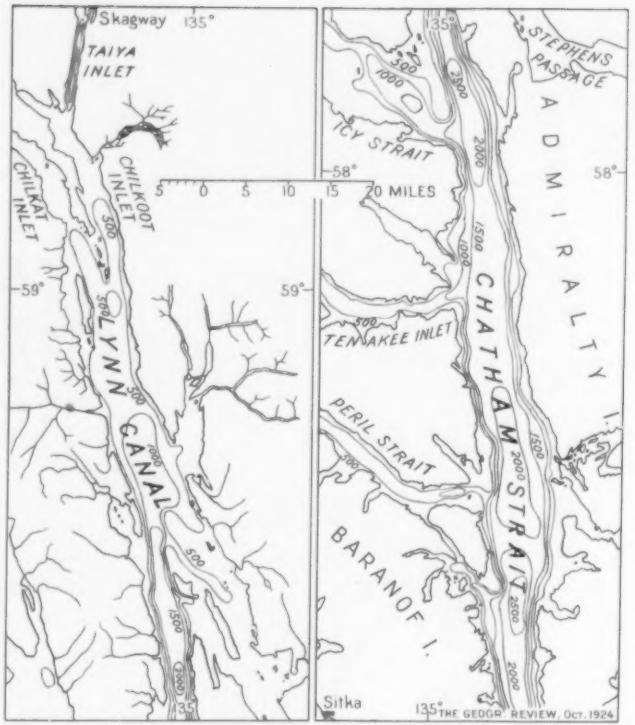

FIG. 15

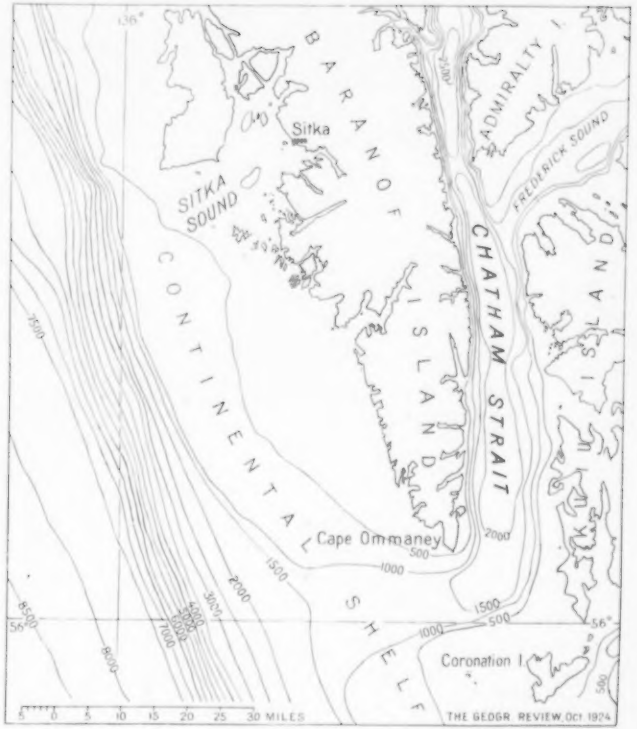

FIG. 16

FIGS. 15 and 16—Maps showing the submarine basins and swells in Lynn Canal-Chatham Strait. Figure 16 shows the fiord extending across the continental shelf into the Pacific Ocean. Contours in feet. Based upon Chart 8002, U. S. Coast and Geodetic Survey.

fiords, their resemblance in general shape to known glaciated valleys—all suggest that they are channels whose form was determined almost entirely by glaciers. The Lynn Canal-Chatham Strait fiord seems to continue across the continental shelf in practically the same manner as a submerged, stream-eroded valley but to differ in form.

Origin of Fiords by Glacial Erosion

Brooks stated in 1902 that, in southeastern Alaska, he was "strongly impressed with the fact that ice action has played a very important part in producing the present topographic forms."[3] Gilbert did more than any one else to establish the fact that glaciers can and do erode below sea level,[4] as indeed Muir concluded from observations more than forty years ago.[5] Gannett concluded that "from Lynn Canal, a fiord ninety miles in length, there have been carried off and dumped into the Pacific more than 200 cubic miles of rock, and from all the fiords of southeastern Alaska the amount removed may be safely estimated at thousands of cubic miles."[6] Tarr made more specific than anyone had previously done the results of faulting, rejuvenation, sinking of the land, etc., showing that the features to be seen in western British Columbia and southeastern Alaska could be produced by none of these exclusively but that glacial erosion has been the main factor.[7]

More recently, however, the adequacy of ice sculpture, wholly or in part, has been called into question and by men who have studied the fiords of southeastern Alaska from the coast as well as from passing ships. F. E. and C. W. Wright seem to the present authors to give a disproportionate emphasis to faulting and indeed to infer a major fault along the axis of Lynn Canal-Chatham Strait without convincing statements of evidence.[8] Still more recently Knopf has described a part of Lynn Canal with a hesitancy about the effectiveness of the glacial erosion which seems to us unwarranted.[9] Grant and Higgins,[10] working in Prince William Sound several hundred miles to the northwest and recognizing glacial erosion in general, have seemed to find it necessary in one case to infer postglacial sinking of

[3] A. H. Brooks: Preliminary Report on the Ketchikan Mining District, Alaska, with an Introductory Sketch of the Geology of Southeastern Alaska, *U. S. Geol. Survey Professional Paper 1*, 1902, p. 35.

[4] G. K. Gilbert: Alaska: Glaciers and Glaciation (Harriman Alaska Expedition, Vol. 3), New York, 1904, pp. 156, 159, and 217.

[5] John Muir: The Mountains of California, New York, 1894, pp. 24–26.

Idem: Notes on the Pacific Coast Glaciers, in "Alaska: Narrative, Glaciers, Natives," by John Burroughs, John Muir, and G. B. Grinnell (Harriman Alaska Expedition, Vol. 1), New York, 1902, pp. 119–135; reference on pp. 128–129.

Idem: Travels in Alaska, Boston and New York, 1915, p. 17.

[6] Henry Gannett: General Geography in "Alaska: History, Geography, Resources," by W. H. Dall and others (Harriman Alaska Expedition, Vol. 2), New York, 1902, pp. 257–277; reference on p. 259.

[7] R. S. Tarr: Glacial Erosion in Alaska, *Popular Sci. Monthly*, Vol. 70, 1907, pp. 99–119.

[8] F. E. and C. W. Wright: The Ketchikan and Wrangell Mining Districts, Alaska, *U. S. Geol. Survey Bull. 347*, 1908, p. 22.

[9] Knopf, *op. cit.*, p. 13.

[10] U. S. Grant and D. F. Higgins: Reconnaissance of the Geology and Mineral Resources of Prince William Sound, Alaska, *U. S. Geol. Survey Bull. 443*, 1910, p. 16.

Idem: Coastal Glaciers of Prince William Sound and Kenai Peninsula, Alaska, *U. S. Geol. Survey Bull. 526*, 1913, p. 72.

the land and in another to infer graben faulting in order to explain certain broad channels, submerged hanging valleys, and straight stretches of fiord which appear to a larger number of other competent observers to require no such complications.[11] It has even been suggested that the hanging valleys in the fiords between Prince Rupert and Vancouver, B. C., are not due to glacial erosion.[12] Lastly a book on fiords has been published by Gregory who believes all fiords to be due to earth movements (faulting).[13]

The Alaskan section of the book by the last-named author contains many misstatements and erroneous conclusions. Figure 54 (p. 293), for example, represents the coast of the Alaska Peninsula west of Afognak and Kodiak Islands as a "non-glaciated coast with fiords." As a matter of fact, this coast has many fair-sized ice tongues, as the senior author of this paper observed when he visited it in 1904. During the maximum of the Glacial Period it had much larger ice tongues, glaciers capable of accounting for all the fiords there present. The same map erroneously shows as "glaciated coasts without fiords" the region between Prince William Sound and Cross Sound, alluding to it in several places in the text as "a long even coast broken only by Yakutat Bay." Here, however, most American physiographers believe fiord making byglacial erosion to be still in progress. Here, moreover, are many fiords, for we must include under the name fiord not only arms of the sea but (*a*) troughs which the sea will fill when present glaciers retreat and (*b*) former arms of the sea partly obscured by glacial and glacio-fluviatile deposits. Gregory completely overlooks: (1) Lituya Bay, one of the finest fiords in the world; (2) the fiords northwest of it near Cape Fairweather; (3) the fiords southeast of Lituya Bay at La Pérouse Glacier, in both the latter cases still brimming with glacier ice; (4) Alsek Canyon, where the mouth of a great fiord is filled with living glaciers and their outwash deposits; (5) troughs at Malaspina Glacier, whose piedmont ice mass and tributary glaciers possibly conceal two fiords equal to Yakutat Bay in extent, which may be revealed at the next glacier minimum, to say nothing of smaller fiords; (6) troughs at Bering Glacier where a similar condition may exist; (7) Copper River Canyon, where a great fiord is partly filled with deposits of glacial outwash. The present occupation of these fiords and canyons by active glaciers and their deposits is an argument for rather than against the glacial molding and excavation of the valleys along this coast.

R. S. Tarr was entirely convinced that glacial erosion was far more important than faulting in making the topographic forms at Yakutat Bay and Russell Fiord. Gregory has no right to say that "Tarr and Martin's memoir shows that the formation of fiord-valleys by trough-faulting is still in progress in Alaska."[14] We seriously question the propriety of

[11] F. C. Schrader and A. C. Spencer; Copper River District, Alaska, *56th Congr., 2nd Sess., House of Repr. Doc. 546*, Washington, 1901, p. 82.

[12] *Compte Rendu Congrès Géol. Internatl.* XII, Ottawa, 1914, p. 1027.

[13] J. W. Gregory: The Nature and Origin of Fiords, London, 1913.

[14] Gregory, *op. cit.*, p. 309.

FIG. 17

FIG. 18

FIG. 19

FIG. 17—A low glacially eroded island in Lynn Canal.

FIG. 18—Looking down Lynn Canal: an extended view made possible by the removal of overlapping spurs through glacial erosion.

FIG. 19—A hanging valley with waterfall in the northern part of Lynn Canal.

Gregory's statement that "in a later memoir Tarr attached less importance to glacial action." In the memoir referred to, Tarr affirmed his own previous statements about glacial erosion most strongly.[15]

Gregory's quotation from John Burroughs (p. 321) appears unfortunate to us, for he overlooks the fact that Burroughs was describing scenery rather than structure when he said: "The edge of this part of the continent for a thousand miles has been broken into fragments, small and great, as by the stroke of some earth-cracking hammer." He certainly did not mean this to be interpreted literally as evidence of his belief in the making of the fiords by some tectonic force, as Gregory implies, any more than Muir meant that the fiords had been made with an embroidery needle when he said: "It is a web of land and water thirty or forty miles wide, and about a thousand miles long, outspread like embroidery along the margin of the continent."[16]

Gregory has printed authority in Spencer for his view that the hanging valleys along Copper River are due to faulting, and in Spurr for errors regarding the Alaska Peninsula. It is difficult to know why Gregory (p. 305) located the Nizina District in Prince William Sound, when it is nearly 150 miles inland beyond a great mountain range. There seems no warrant for the view that the evidence of slightly larger ice masses in Seward Peninsula (pp. 294–297 and 317) makes the fiordless American coast of Bering Sea a "glaciated coast without fiords." The authors cannot follow the reasoning that concludes (p. 318) that absence of fiords at right angles to the coast ("radial") in southeastern Alaska and British Columbia proves that "the development of the fiords appears quite independent of the glaciation of the country," or that the general plan and detailed topography "are alike inexplicable on the view that their plan was due to river or glacial erosion." We deny Gregory's statement (p. 319) that "in Alaska lakes are abundant in the non-glaciated areas as well as in the glaciated." We cannot agree with the generalization (p. 317) that "the distribution of fiords in Alaska does not coincide with the distribution of glacial activity." We regret Gregory's dictum (p. 306) that if there were fiords along the coast between Prince William Sound and Cross Sound "their ends should already have been unmasked," for we know of many troughs there that we should call fiords, to say nothing of the well-known fiord at Lituya Bay already alluded to. Because of such errors, upon which Gregory has based important conclusions, and because of many frank differences of interpretation, not enlarged upon here, we cannot accept Gregory's conclusion (p. 324) that the Alaskan fiords "appear to be of tectonic rather than of glacial origin."

The present paper is, therefore, written in support of the original contention of Muir, Brooks, Gilbert, Gannett, Tarr, and others. It is based

[15] R. S. Tarr: The Yakutat Bay Region, Alaska, Physiography and Glacial Geology, *U. S. Geol. Survey Professional Paper 64*, 1909, pp. 116–119.

[16] John Muir: Alaska, *Amer. Geologist*, Vol. 11, 1893, pp. 287–299; reference on p. 287.

FIG. 20

FIG. 21

FIGS. 20 and 21—Hanging valleys in the Lynn Canal-Chatham Strait system. Figure 20 is in the northern part of Glacier Bay; Figure 21 near Skagway. Such forms are evidence for the conclusion that glacial erosion rather than faulting or sinking of the land has produced the present fiord.

upon field work on shore in Lynn Canal-Chatham Strait as in the case of the work of the Wrights and Knopf, in Prince William Sound, as in the

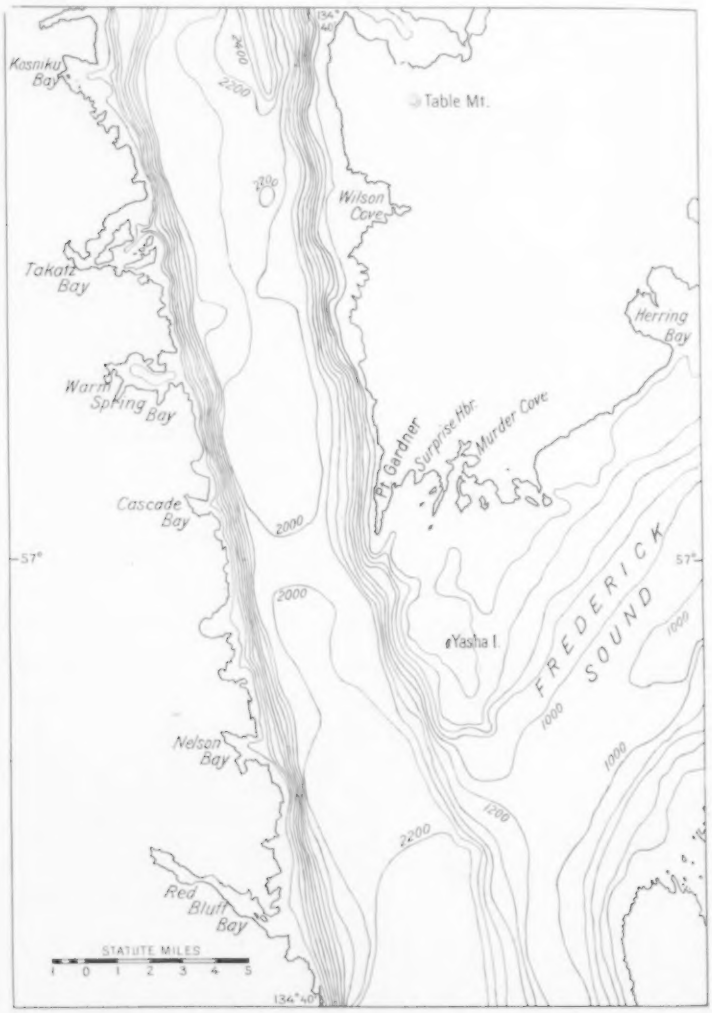

FIG. 22—Map showing a submarine hanging valley at the junction of Frederick Sound with Chatham Strait. The valley hangs 1200 feet. Note also the submarine valley of Warm Spring Bay hanging 1700 feet. Based upon Chart 8250, U. S. Coast and Geodetic Survey.

case of Grant and Higgins, and in Glacier Bay, Lynn Canal, and Yakutat Bay, as in the case of Gilbert, Gannett, Muir, Tarr, and others. It is based also upon a more detailed study than has been made before of the portions of Lynn Canal-Chatham Strait below sea level. The maps and cross sec-

tions here presented seem to us to furnish clear evidence that the form of Lynn Canal-Chatham Strait is due to glacial erosion. The junior author has drawn submarine contours on all available charts of the fiords of southeastern Alaska, upon the basis of the soundings published by the U. S. Coast and Geodetic Survey. This contouring has been done upon maps on scales of 1:80,000 in some cases and 1:200,000 in others. These submarine contours we have compared with the contours above sea level on all the existing maps of the International Boundary Survey and the U. S. Geological Survey for this region, so that the maps and the cross sections here presented constitute only a small portion of the material studied by us.[17] Our several seasons of observations in the field lead us to the same conclusion suggested by the map study, namely that faulting, stream erosion, and sinking of the land have played a subordinate rôle in the production of such an arm of the sea as Lynn Canal-Chatham Strait, where we believe that the major forms, below as well as above sea level, are due to glacial erosion.

The Direction of Ice Movement

The Lynn Canal-Chatham Strait fiord, whose main channel now contains no tidewater glaciers, was brimful of ice at the maximum of glaciation in Alaska. The ice tongues of Glacier Bay, Taku Inlet, and other tributary fiords are shrunken representatives of the Lynn Canal ice stream. It was

[17] U. S. Coast and Geodetic Survey Charts 8300 and 8250 show the whole length of Lynn Canal-Chatham Strait on the scale of 1 : 200,000; for its eastern branches and other fiords southward to Dixon Entrance on the same scale see Charts 8200 and 8102; for more detailed charts of southern Lynn Canal and its western branch, Icy Strait-Cross Sound, see Charts 8303, 8302, and 8304 on the scale of 1 : 80,000; for the coast of the Pacific Ocean from Chatham Strait to Dixon Entrance see Chart 8152 on the scale of 1 : 229,000; for Glacier Bay, the northern extension of Icy Strait, see Chart 8306 on the scale of 1 : 160,000; for the mouths of the Chatham Strait, Cross Sound, and Dixon Entrance fiords on the continental shelf see Chart 8002; for some of the smaller submarine hanging valleys see harbor charts 8242 and 8246. Chart 8002—Dixon Entrance to St. Elias—shows the whole fiord system from southeastern Alaska to the Copper River. Chart 3089—Northwest Coast of America and Inland Passages—shows the fiords from Mt. St. Elias through Lynn Canal, southeastern Alaska, and British Columbia to Puget Sound, Washington, on the scale 1 : 1,200,000.

There are other government maps as follows: *U. S. Geological Survey:* "Juneau Special Map," scale 1 : 62,500, contour interval 100 feet, 1904; "Eagle River Region," scale 1 : 62,500, contour interval 50 feet, 1912; "Juneau Gold Belt," scale 1 : 250,000, contour interval 250 feet, 1905; "Berners Bay Special Map," scale 1 : 62,500, contour interval 50 feet, 1908; "Juneau and Vicinity," scale 1 : 24,000, contour interval 50 feet, 1918; "Copper Mountain and Vicinity," scale 1 : 62,500, contour interval 100 feet, 1908; "Kasaan Peninsula," scale 1 : 62,500, contour interval 50 feet, 1915; *Alaskan Boundary Tribunal and International Boundary Commission:* "Atlas of Award, 25 sectional maps and index map showing the line fixed by the Tribunal," sheets 10, 11, 12, 13, 14, 15, 16, 16a, 17, 18, 19, scale 1 : 160,000, contour interval 50 feet, published as *Senate Doc. No. 162, 58th Congr., 2nd Sess.*, Washington, 1904; "International Boundary between the United States and Canada from Cape Muzon to Mt. St. Elias," sheets 6, 7, 8, 9, 10, scale 1 : 250,000, contour interval 250 feet, 1922–1924, eventually to be published in an atlas of 13 sheets; *Alaska Road Commission:* "Map of Alaska, prepared by the American Geographical Society for the Alaska Road Commission, and published jointly, 1923," scale 1 : 1,250,000, contour interval 1000 feet; *U. S. Forest Service:* Tongass, Sheet 1, scale approximately 1 : 500,000, contour interval 1000 feet; for forest and water-power maps showing glaciated details of parts of the fiord walls and tributary land valleys with contours see the following: Admiralty Island, scale 1 : 63,360; Craters, Long, and Tease Lakes, scale 1 inch to 2000 feet; Keku Strait, scale 2 inches to 1 mile; East Coast Baranof Island, scale 2 inches to 1 mile; Suloia Lake, scale 1 inch to 1500 feet; Port Snettisham, scale 2 inches to 1 mile; Windham Bay, scale 2 inches to 1 mile; Silver Bay, scale 1 inch to 1500 feet. (Certain of these maps are available only as black and white proof sheets.)

A geological map of the whole inner fiord system of the Canadian Coast Range from Skagway to Dixon Entrance, on the scale of 1:250,000, may be made by putting together Plate 37 in Spencer's Bulletin 287 and Plates 2 and 3 in the Wright's Bulletin 347.

a valley glacier 250 to 300 miles long and 8 to 25 miles wide throughout most of its extent. At the flood stage of glaciation it must have been 3500 to 6000 feet in thickness, as is shown by the height at which till, striae, and erratics are found on the fiord walls, combined with the depth of water in the fiord. The tributary fiords were completely filled with flowing ice.

The direction of ice movement coincided generally with the trend of the present fiords, so far as striae have been observed. The distribution of erratics from the igneous mass of the Coast Range batholite supports this conclusion of southward and southwestward-moving ice tongues. This suggests that the ice was guided initially by preglacial valleys. The even sky line and the complex rock structures on the fiord walls and in the islands suggest that the preglacial drainage may have been inherited from a previous cycle when the mountains were reduced to a peneplain. The trend of Lynn Canal-Chatham Strait is diagonal to the strike of the sedimentary rocks. This may be caused by faulting, as discussed later, or it may mean that the fiord is the glacially-enlarged valley of a rejuvenated preglacial stream that acquired this course as a result of the uplift and tilting of an ancient peneplain. The minor topographic features, on the other hand, are directly related to the rock formations. Weak rock underlies many of the bays and tributary fiords. Resistant rock forms the peninsulas and islands.

The Rôle of Faulting

Faulting may very well have played a part in the formation of the fiords. If it did, the authors' view is that it was a minor part. The most striking suggestion of faulting is the length and straightness of Lynn Canal-Chatham Strait. It would be unusual if a river had acquired so direct a course for 250 miles as a result of mere tilting of a peneplain. The straight fiord is not due to any one stratum of weak rock, for it cuts at an angle of about 30° across the strike of the sedimentary and metamorphic rocks and the igneous masses which intrude them. Faulting is a natural explanation of the straightness of Lynn Canal-Chatham Strait. Our view, however, is that, if there is a fault line or shatter belt here, it merely determined the direction of the fiord. Its form alone—profile and sections—shows clearly that it is not a rift valley made by faulting. Faulting, as it seems to us, may have merely provided a zone of shattered and weak rock which guided the preglacial river and the ice stream of the Glacial Period. The absence of rift faulting is best proved by the absence of faults in the tributary fiords, where the pattern and cross section are identical. Nordenskjöld long ago suggested that the joint systems in Lynn Canal agree in direction with the trend of the fiord, though he did not imply that the fiord was not of glacial origin.

The Wrights and other workers in the area may have had this conception of the rôle of faulting, that the topographic form was not made by faulting, but that faulting merely provided a long, narrow strip of weak rock. The

absence of specific statements to that effect appears to have misled students, especially Gregory, who have never visited the region.

Absence of Evidence of Drowning of Valleys

There was a time when the very presence of fiords was taken as indubitable proof of sinking. This was because the conception of glacial erosion, below sea level as well as above sea level, had not yet been established. The fiords of southeastern Alaska present no conclusive evidence of submergence of the land. The plan and the profiles of the present fiords are distinctly different from what would be made by the drowning of normal (non-glaciated) stream valleys. They are typical of glacially-overdeepened and widened valleys or of submerged glaciated valleys; but sinking of the land is not a necessary factor in their formation. If it were argued that the Lynn Canal-Chatham Strait fiord involved sinking of the land without submarine glacial erosion, then it would be necessary to assume that the land had been submerged after having been nearly 3000 feet higher, for Chatham Strait is at least 2900 feet deep. Differential warping of 3000 feet seems improbable in view of the lack of warping of the upland surface. Our view is that there is no evidence of and no necessity whatever for invoking submergence. The pattern and form of the fiords, save for straightness alone, are those of glacial erosion. As the ice tongues melted back, the waters of the sea, according to our view, came in and occupied the fiords without sinking of the land. This is just what happened in Glacier Bay between 1794 and 1924, when a fiord more than 60 miles long was revealed by the recession of Grand Pacific Glacier, Muir Glacier, and adjacent ice tongues. Muir stated this very well in 1894, referring to all the fiords of southeastern Alaska: "The intricate labyrinth of canals, channels, straits, passages, sounds, narrows, etc., between the islands, and extending into the mainland, of course manifest in their forms and trends and general characteristics the same subordination to the grinding action of universal glaciation as to their origin, and differ from the islands and banks of the fiords only in being portions of the pre-glacial margin of the continent more deeply eroded, and therefore covered by the ocean waters which flowed into them as the ice was melted out of them."[18] Gilbert, however, concluded on other grounds that the preglacial stream valley in Lynn Canal may have been slightly below present sea level, being related to a lower base level. He conceived the glacial degradation as possibly averaging more than 1000 feet but concluded that "the existence of a fiord . . . . is not demonstrative of a relatively low base-level at the time of its excavation."[19]

Uplift is certainly the latest known movement. This is established by the presence of shells of marine animals of Pleistocene age in deposits (1) on Pyramid Island, Chilkat Inlet, (2) on Lynn Canal near Eagle River, (3)

[18] Muir, Mountains of California, pp. 24–26.
[19] Gilbert, *op. cit.*, p. 217.

at Gastineau Channel near Juneau, (4) near Portland Canal east of Dixon Entrance, and (5) throughout the Canadian fiords to the south. The fossils have been observed by Krause,[20] Dall,[21] Knopf,[22] Dawson,[23] McConnell,[24] and others. The fossiliferous deposits on Pyramid Island are a little over 60 feet above sea level. Those near Lynn Canal at Eagle River and Juneau are at elevations of 100 to 200 feet. They demonstrate that one of the latest, if not the last, earth movement here was an uplift of 60 to 200 feet. The marine deposits near Portland Canal at the southern border of Alaska prove the uplift there to have been nearly 500 feet. Portland Canal is 300 miles southeast of Pyramid Island. Thus it appears that there was tilting during the uplift, amounting to a foot or two per mile. There was also uplift for at least 300 miles to the south,[25] as in the Queen Charlotte Islands, at and near Texada Island,[26] and on Vancouver Island.[27]

There are no facts that appear conclusively to disprove sinking of the land in the fiords of southeastern Alaska and western British Columbia. On the other hand, there is nothing in the situation that suggests or requires it. As the evidence clearly proves a very recent and widespread uplift, it seems most natural to assume that this was not only the latest movement but also the only postglacial movement of the coast.

We conclude that Lynn Canal-Chatham Strait is a fiord in which glacial erosion, rather than faulting or normal preglacial stream erosion, has been the main agency and that sinking of the land is not an essential factor, if indeed submergence has taken place at all.

[20] A. Krause: Das Chilcat-Gebiet in Alaska, *Zeitschr. Gesell. für Erdkunde zu Berlin*, Vol. 18, 1883, pp. 344–368; reference on p. 354.

[21] W. H. Dall: Neozoic Invertebrate Fossils, in "Alaska: Geology and Paleontology," by B. K. Emerson and Others (Harriman Alaska Expedition, Vol. 4), New York, 1904, pp. 99–122; reference on pp. 120–121.

[22] Knopf, *op. cit.*, p. 33.

[23] G. M. Dawson: Additional Observations on the Superficial Geology of British Columbia and Adjacent Regions, *Quart. Journ. Geol. Soc.*, Vol. 37, 1881, London, pp. 272–285; reference on pp. 279–282.

[24] R. G. McConnell: Portions of Portland Canal and Skeena Mining Divisions, Skeena District, B. C., *Geol. Survey of Canada Memoir 32: Geol. Ser. No. 25*, Ottawa, 1913, pp. 22–23.

[25] J. A. Bancroft: Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, B. C., *Geol. Survey of Canada Memoir 23*, Ottawa, 1913, pp. 121–123.

[26] R. G. McConnell: Texada Island, B. C., *Geol. Survey of Canada Memoir 58: Geol. Ser. No. 48*, Ottawa, 1914, p. 46.

[27] C. H. Clapp: Southern Vancouver Island, *Geol. Survey of Canada Memoir 13*, Ottawa, 1912, p. 151.

THE TERRACES OF THE LAKE MELVILLE DISTRICT, LABRADOR*

By E. M. KINDLE
Geological Survey of Canada

Labrador's recent geological history has been recorded on the bleak and barren cliffs of the eastern coast in bold and legible characters. No fisherman can fail to recognize the autograph of the sea in the elevated boulder beaches and terraces of sand (Fig. 1), which may be seen in many places 200 feet or more above the present sea level and which at scores of localities look almost as fresh and perfectly preserved as those now being built by the sea. Beaches of glacial boulders such as justify Packard's characterization of "a truly noble beach" occur all the way from Hamilton Inlet to the western end of the Strait of Belle Isle, where Twenhofel[1] observed at one locality eight beaches, the highest of which was 350 feet above high tide. Terraces, however, are seen in their best development along the interior waterways. In the Hamilton Inlet and Lake Melville region they run inland more than 200 miles from the coast along the fiordlike valleys and rivers.

TERRACE BUILDING

In some localities the terraces consist of a series of great steps, the lowest of which is under water. Many of the best developed occupy the sides of stream valleys and often show considerable width. None of them represent the work of "a meandering and swinging stream, slowly degrading a previously aggraded valley;"[2] neither are they wave-cut or wave-built terraces. They have been formed in lakelike expansions of river valleys in which tidal currents were the chief factors in the movement and deposition of the sediments. The disposition of the lower or younger terraces at the head of Mulligan Bay, Lake Melville, parallel with the shore line at the head of the bay and at right angles to the direction of the river entering it, illustrates the entire independence of river activities. Here ten terraces occur within a quarter mile of the lake shore on the east side of the river, the highest lying about 25 feet above the lake.

In order to analyze the process of terrace building three factors may be considered. These are the sediments contributed by the small side streams to the trunk streams of the wide valleys, the tidal currents, and the river

* Published with the permission of the Director of the Geological Survey of Canada. The writer's complete report on the region will be published under the title "The geography and geology of the Lake Melville District, Labrador Peninsula," as a memoir of the Geological Survey of Canada.

[1] W. H. Twenhofel: Physiography of Newfoundland, *Amer. Journ. of Sci.*, Ser. 4, Vol. 33, 1912, pp. 1-24; reference on p. 22.

[2] W. M. Davis: River Terraces in New England, *Bull. Museum of Comp. Zoöl. at Harvard College*, Vol. 38 (Geol. Ser., Vol. 5), 1902, pp. 279-346; reference on p. 284.

currents. Much of the sand drops to the bottom near the small valley mouths, where the current velocity is reduced by contact with a larger stream, and moves along the shore chiefly under the influence of tidal currents, while the fine sediment of the tributaries remains long in suspension and has a correspondingly wide and uniform distribution. Where the shore contours have been most favorable to early checking of the near shore flood currents by the ebb current, terraces have been formed if an abundant supply of sand was available. It is in the narrow near-shore zone, along which much of the coarse sediments travel and where the reversal

FIG. 1—Sand terraces at Moliak Cove, Lake Melville. Diagrammatic section of lake bottom mud and sand terraces at the right of the picture illustrate the contemporaneous development of mud and terrace deposits and progressive overlap of the former by the latter. (This and the following figures are from sketches by A. Miles and L. Kindle.)

of the tidal current first occurs, that most of the sand load is dropped and the broad flat-topped embankments are built up. "The flood current generally commences to run up the sides of a river while the ebb is still running down in the center."[3] In the Narrows at Rigolet the tidal currents attain a velocity of six to seven knots an hour in mid-channel at spring tides with very little slack water. In mid-channel the tidal streams run three and a half hours after high water by the shore. This indicates the relatively long periods of slack water along favorably located parts of the shore where the tidal current sand load may come to rest during most of the tidal cycle.

TERRACES OF LAKE MELVILLE AND THE BACKWAY

The complexities of current behavior result often in the building of a splendid series of terraces on one side of a valley and none at all on the opposite side. This has occurred at the Narrows, where on the southeast side a series of terraces border the shore while the northwest shore is without a single terrace. Throughout most of the late Pleistocene and recent uplift of the region a deep bight has characterized the southeast shore. So long as this bight persisted the development of terraces continued as a

[3] W. H. Wheeler: A Practical Manual of Tides and Waves, London, 1906, p. 96.

result of greatly reduced current velocity in this expanded part of the Narrows. Uplift and terrace growth have now reduced the former bight to a nearly straight shore line interrupted only by one or two small spits, and terrace building is at an end on this particular stretch of shore. The youngest terrace comes to the edge of the water, but a rock reef lies below the surface instead of a growing terrace such as many localities show. The highest terrace south of the Narrows rises about one and a fourth miles back from the shore and has an elevation of 210 feet above high tide (Fig. 2). In front of it is the wide top of the next lower terrace, which is partly forested and has one or more shallow lakes and some muskeg on its approximately flat surface, which slopes gently toward the north. The front of this terrace rises gradually from 20 feet above high tide at the mouth of a brook opposite Rigolet to a maximum of 90 feet some two miles south. The face of this 90-foot terrace, as it is followed southwest from the brook mouth, is seen to split up into smaller terraces, the latest of which approaches the present shore line. Ten of these small terraces are recognizable at one point. Study of such a terrace as this, where a single terrace face splits into several minor terraces, should dispel the inference, suggested by a cursory examination of stair-step terraces, that minor terraces represent pauses in the uplift of the region. Such terraces record modified conditions of terrace development through which changes in depth, shape of shore line, supply of material, or other factors have initiated a new terrace along some part of the front of the older one.

One of the finest and most instructive sets of terraces in the region may be seen at Moliak Cove near the southwestern end of the Narrows. Here, as in the Narrows, the terraces are confined to one side of the valley. Beyond the head of the bay they continue inland for an unknown distance along a through valley now occupied only by a small lake and brook (see Fig. 1). At this locality three well developed terraces rise respectively 12 feet, 120 feet, and 310 feet above high tide. A fourth poorly defined terrace stands at about 20 feet. A fifth, the youngest of this series, is now being built just below or partly below low tide. It extends out from the foot of the first subaerial terrace from 10 to 75 yards and then descends to deep water and mud bottom with the same steep grade as the fossil terraces inshore from it.

Underwater terraces are now forming along parts of the bottom of the Backway, which is a finger lake type of valley closed seawards but connected with Lake Melville. Most of the terrace building along the Backway basin has taken place on the south side of the waterway. Its best development is seen a few miles below the entrance. The sketch (Fig. 3) shows at this locality a main or highest terrace rising 310 feet A. T. (aneroid) connecting together in bar fashion two Precambrian hills. Between this major terrace and the shore about six minor terraces are recognizable. Some of these are modified by sand spits developed during the withdrawal of the sea.

FIG. 2—General view of the south side of the Narrows, showing sand terraces.

FIG. 3—Sand terraces connecting hills of Precambrian rocks on the west side of the Backway.

The upper end of the Lake Melville basin, known as Goose Bay, is being rapidly filled with sand annually poured into it by the Hamilton River during the flood season. Tidal currents distribute the sand around the margin of the basin as it is received, forming a continuous subsurface terrace shelf, which is generally from one-half to two fathoms under water and from one-quarter to two miles wide. This growing terrace surrounds a basin that ranges in depth from 8 to 34 fathoms. In case the present stage of emergence is maintained for a long period, Goose Bay will be filled to a level sand plain with the Hamilton River flowing through the middle and joining the lake some 15 miles to the eastward of the present mouth. At the eastern end of Goose Bay the 16,000-foot passage into Lake Melville has already been largely closed by the encroaching underwater terraces, which now leave a channel only about half a mile wide and two and a half miles long. In case emergence continues as it has during late Pleistocene times, the building of a series of terraces will accompany the extinction of Goose Bay.

River Valley Terraces

In the river valleys, as a result of elevation of the land and the retreat of the lakelike tongues of the sea, terrace building is at an end. But the great fossil terraces rising often 200 feet or more above the rivers remain. Along the valleys of the Naskaupi and its western tributary, the Red River, terraces are splendidly developed in places. A short distance above the mouth of the Naskaupi a mid-valley, or island, terrace area has developed as a result of the junction of the Little River and Naskaupi River valleys. Four terraces mark this island, rising above low water in the river 8, 58, 78, and 103 feet. Another great sand terrace rises just above the junction of the Red and Naskaupi valleys with an elevation of 200 feet above the rivers.

The highest terrace observed at a considerable distance from the coast was seen west of the Naskaupi a few miles up the Red River, where the terrace top rises 280 feet above the river. If allowance is made for the grade of the river valley this figure is very close to the elevation of the one at Moliak Cove.

Significance of the Terraces

The conditions that have been shown to control the development of terraces in this region are local in character. Consequently the correlation of terraces other than those representing the maximum submergence is impracticable. Terraces formed at different stages of uplift represent only terrace conditions that appear and disappear in conformity with certain topographic adjustments to the water level.

The two maximum terrace measurements (aneroid) made in the region are both recorded at 310 feet. It is probable that the maximum submer-

gence did not exceed this figure more than 15 feet, so that 325 feet may be considered a close approximation to the maximum submergence experienced by this region during Pleistocene times. This figure is a little higher than Daly's estimate[4] of the maximum amount of the emergence in the Hamilton Inlet district, which was based on other kinds of evidence.

[4] R. A. Daly: The Geology of the Northeast Coast of Labrador, *Bull. Museum of Comp. Zoöl. at Harvard College*, Vol. 38 (Geol. Ser., Vol. 5), 1902, pp. 203–270; reference on p. 259.

ANTARCTIC GLACIERS

By Harry Fielding Reid
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The volume "Glaciology" of the British (Terra Nova) Antarctic Expedition[1] contains an immense number of observations on the various types of ice and glaciers of Antarctica. The large scale of the Antarctic continent, the continuously low temperatures, and the severe blizzards prevented the making of repeated visits to the various glaciers so that intensive studies of them were impossible; but one can only admire the energy, pluck, and endurance that were necessary to collect all the information contained in this volume.

From this and other expeditions we can form a fairly good general conception of the Antarctic continent and its characteristics. But it must be remembered that exploration has only touched the coast here and there. The continent has an area of about 5,000,000 square miles; it is approximately circular, with two known deep indentations, the Ross Sea and the Weddell Sea, nearly opposite each other. It is roughly centered about the pole. The surface rises gently from the coast to a height of nearly 10,000 feet near the pole and is nearly all covered with ice and snow. South of New Zealand a great fault runs towards the pole letting down a block covered by the Ross Sea and Ross Barrier. King Edward VII Land seems to bound this block on the east, but little is known of it. The fault bends around to the southeast near the parallel of 80°, and no information regarding it is available beyond the meridian passing through the east side of the Ross Barrier. The region along the fault zone is known as South Victoria Land. The zone itself is a scarp leading from sea level up to the high plateau; and along the zone rise high mountains, up to 15,000 feet. Ice overflows from the plateau and streams down across the zone in a few large glaciers. Smaller glaciers rise on the flanks of the mountains in the zone itself. The glaciers tapping the plateau, and some others, have very small gradients. The Beardmore Glacier, the largest known valley glacier in the world, with a length of 120 miles and a breadth varying between 15 and 35 miles, has an average gradient of about two-thirds of a degree. The region explored by the British Expedition embraces an extent of about 1000 miles in the neighborhood of the fault zone, about 300 miles of the high plateau in the neighborhood of the pole, and a part of the plateau farther north.

The authors describe the various characteristics of the glaciers and emphasize the considerable differences between them and glaciers of the

[1] British (Terra Nova) Antarctic Expedition (1910–1913): Glaciology, by C. S. Wright and R. E. Priestley. 581 pp.; maps, diagrs., ills. Harrison & Sons, Ltd., for the Committee of the Captain Scott Antarctic Fund, London, 1922.

temperate zone. The numerous excellent half-tones and figures in the text, many of them diagrammatic, add much to the clarity of the descriptions. We shall attempt to see what light their observations throw on the general theory of glaciers.

Parts of a Glacier

A complete glacier consists of two parts, the reservoir, where there is accumulation and the dissipator, where there is wastage; these regions are separated by the *névé* line, and there is continual flow from the first to the second. The general directions of the lines of flow are known and clear

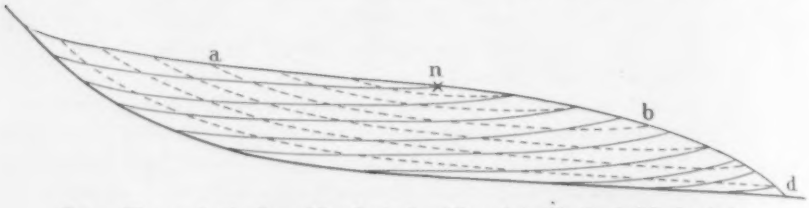

Fig. 1—Diagram showing lines of flow (broken) and lines of stratification (solid) of a glacier.

up many phenomena.[2] They and the strata are shown diagrammatically in the figure. Each point of the reservoir where snow is collected is connected by a line of flow with a corresponding point in the dissipator, where that same snow, converted into ice, is dissipated. The higher up the beginning of a line of flow is in the reservoir, the farther down its end lies in the dissipator; and the snow that accumulates at the very head of the reservoir only comes to the surface at the end of the glacier. In the reservoir the movement has a component downward into the glacier, in the dissipator towards the surface.

It is convenient to divide glaciers into two classes—complete and incomplete. All the accumulation of a complete glacier is lost by ablation and melting in the dissipator. In an incomplete glacier a part of the dissipator is missing, either because it falls over a cliff or because it breaks off and floats away as icebergs. The surface phenomena of the reservoir and of the dissipator are quite different.

All the large glaciers of the Antarctic, and especially those that tap the plateau ice, are incomplete and consist almost entirely of the reservoir only; though in places stretches of the dissipator exist. A large proportion of the observations of the explorers, therefore, refer to the reservoir; this is fortunate, for the reservoirs of temperate glaciers have received much less attention than the dissipators.

[2] S. Finsterwalder: Der Vernagtferner, *Wiss. Ergänzungsheft zu Zeitschr. Deutsch. und Oest. Alpenvereins*, Vol. 28, 1897.

H. F. Reid: The Mechanics of Glaciers, *Journ. of Geol.*, Vol. 4, 1896, pp. 912–928.

Idem: De la progression des glaciers, leur stratification et leurs veines bleues, *Compte-Rendu Congrès Géol. Internatl. VIII, Paris, 1900*, pp. 749–755.

Accumulation

Anticyclonic conditions prevail in the Antarctic because of the large expanse of snow-covered surface. The air, rendered cold and heavy by contact with the snow, slides down the slopes radially and is deflected to the left by the earth's rotation, so that southeasterly winds predominate, especially during blizzards. But the large valleys of the fault zone guide the winds locally so that in this region the blizzards blow from the west. These winds are of great violence and blow off much or all of the snow from the valley portion of the glaciers and deposit it again lower down or carry it out to sea. As the air slides down the slopes its place is taken by descending currents, which become heated adiabatically and bring about much ablation.

We thus understand how in certain regions the annual ablation is greater than the deposit and how parts of true dissipators exist, with their normal characteristics, in spite of the fact that even the summer temperature of the Antarctic continent is below the freezing point. Indeed some stretches of dissipator are practically free of snow throughout the year. Without the winds the snow line would lie everywhere at sea level. The accumulation of snow is very spotty and depends much on the local topography. Its amount is small. The recovery, after six and a half years, of an old *dépôt* on the Barrier showed an annual accumulation of about 15 inches of snow of specific gravity 0.5, or 7½ inches of water. In some sheltered places it must be more, in some places less; and, as noticed, in places ablation predominates. The heaviest snowfalls seem to come from gentle northwest winds, which bring moisture from the warmer ocean; as much as 17 inches of snow fell in one such storm. The snowfall is heavier near the borders of the continent than it is farther south; but the accumulation is patchy and depends on the winds. The drift snow on the lower stretches of the glaciers may be looked upon as the reservoirs of parasite glaciers such as may be seen in complete form in the Swiss Alps. The snow on the high plateau is soft and incoherent; it seems to be like the snow sometimes encountered in the high Alps when cold weather follows a storm; or like that found by Whymper on the top of Chimborazo. The authors think there is a very small accumulation on the high plateau. That the ice is flowing down the plateau is evident from the behavior of ice on a slope, the existence of crevasses on the slopes, and the actual measurement of the movement by Drygalski near the Gaussberg.

Ablation

This term refers, not to the disappearance of recently fallen snow, but to the loss of older ice from the dissipator. The principal causes of ablation are direct or reflected solar radiation, reradiation from heated rocks, condensation of moisture from the atmosphere, rain, and the sublimation of ice. Condensation of moisture is an important factor with temperate

glaciers and deserves more emphasis than it has received. I think it has much to do with the rounding of angles, such as the edges of crevasses, etc. In the Antarctic it acts differently: any condensation is in the form of hoarfrost, ice flowers, etc., and is a means of accumulation (though insignificant) and not of ablation. Rain is practically unknown in Antarctica. The authors ascribe to sublimation of the ice by the warm dry winds blowing down the valleys a principal rôle in the ablation of Antarctic glaciers; it is quite unimportant in temperate zones. But the most striking effects are due to radiation. The sun never rises high in Antarctica, but it shines for long hours in the summer. Its rays strike the ends of the glaciers at a high angle; and, especially where silt bands are abundant and add to the absorption, the ablation is strong. As the silt bands predominate at the lower levels of the ice and as the upper layers move more rapidly than the lower, a somewhat overhanging cliff is developed; and from time to time ice breaks off the upper part and falls to the ground. The form is not confined to the ends; but reflected radiation and reradiation from the walls of the valley develop the same form along the sides and leave the so-called "radiation gully" between the ice and the valley sides. This gives to the smaller glaciers of northern Greenland and Antarctica a striking appearance, which is never seen in temperate latitudes. It is rather remarkable that this form may not only be one of equilibrium, but it may be stable; whereas the rounded ends of temperate glaciers are unstable.

Absorption of radiation by thin moraines, by small stones and dust, is extremely effective in melting the ice. During a few days in summer a considerable quantity of water runs off the surface. The melting is naturally selective, being confined to the immediate vicinity of the débris, and cliffs and pinnacles of fantastic shapes result. These are well developed on the northern side of the lower part of the Koettlitz Glacier, where the heights of the cliffs and pinnacles and the existence of surfaces of discontinuity suggest that we have here the results of many seasons' ablation.

Moraines

The explorers were struck with the scarcity of moraines in the Antarctic. This is due to two causes: the small amount of exposed rock and the fact that nearly all the region is reservoir. Moraines do not remain exposed in the reservoir in any latitude; however, the annual accumulation is so small in the Antarctic that a moraine may be exposed on the surface of the reservoir for a short distance from its origin before it is covered up. A moraine may appear on the stretch of dissipator, be covered by the drifted snow lower down, and again appear farther on—thus giving the curious phenomenon of an intermittent moraine.

Moraines without evident origin also were seen on the dissipator or in the terminal face of a glacier. The explorers were inclined to consider the first as due to the upturning of the strata or to ground moraine brought to the

surface by shearing of the ice, as Chamberlin has suggested; and the latter as due to such shearing or to the sinking of stones through the ice by their own weight. The explorers found, however, little evidence in support of their hypothesis, and our figure shows that it is unnecessary. Suppose there is at *a* a junction of two tributaries, or the reunion of the ice after passing around a nunatak; as the ice flows on, the inner boundaries of the two branches, with their ground moraines, will form a highly inclined wall strewn with moraine and extending downwards from *abd* to the bed of the glacier; but no moraine will appear at the surface between *a* and *b*. This, I think, is the complete explanation of medial moraines starting at some point of the dissipator and growing greatly as more material is melted out of the ice. The great medial moraines of the Aletsch Glacier are excellent examples. In the reservoir the snow usually slopes up against the mountains, and individual stones may slide or roll well out upon the glacier and later come to the surface, or to the terminal face, away from the moraine. Sometimes a slide of rocks may be shot out upon the reservoir and be incorporated in the glacier spread out upon a stratum. It will come to the surface in the dissipator in a form somewhat different to that of a medial moraine. When two glaciers unite, the strata are necessarily bent up; and, as mentioned, the surface of junction contains some ground moraine. Even under the large medial moraines of Alpine glaciers this junction is not heavily filled with moraine material; the very small amount seen in the Antarctic glaciers strengthens the conclusion, reached by the explorers, that these glaciers are not now greatly abrading their beds. The highly inclined dirty bands seen on the ends of glaciers or on the sides of icebergs probably mark the junction of glaciers. The moraines on the dissipator are quite normal. Where the material is scarce and its component blocks are not large, it is apt to melt into the ice; where the material is sufficient to protect the ice it forms ridges. Large blocks stood up as glacier tables. Very little ground moraine was seen. The larger glaciers end in the sea, and the base is invisible; the small glaciers ending on land are probably frozen to their beds. Lateral moraines, which are characteristic of the dissipator, also were scarce, because the rock falling from the mountains fell, for the most part, into the radiation gully and not upon the ice. Where the gully had been filled with drifted snow some lateral moraine was formed.

Glacier Grains

The explorers made many interesting and valuable observations of the development of ice crystals under different meteorological conditions, but we must reluctantly pass them by. They studied the transformation of snow into ice in the glaciers and introduce a useful distinction between *névé* snow and ice. There is much air between the fallen snow crystals; as long as this air remains between the growing crystals, we have *névé;* but, when the crystals have grown and include the air bubbles, we have

ice. They found the glacier grains similar to those in temperate glaciers but smaller; and they refer this to the very low temperatures of the Antarctic. They discuss at length the growth of these grains, and, as there can be no question of melting here, they adopt Chamberlin's view that molecules of ice pass from crystal surfaces of larger curvature to those of smaller curvature. No other explanation is at hand, but this one presents difficulties. It would lead to the formation of plane faces between the crystals, and growth would then cease. In the Antarctic, as in temperate zones, glacier crystals interlock. We often find a small extension of one crystal completely surrounded by another crystal. It is exactly in condition to be rapidly absorbed, but such interlocking is common and not exceptional. The most effective condition for the growth of crystals is the presence of water, which, of course, brings the ice to the melting temperature; and many examples are cited. But the mere presence of ice may convert the snow in contact with it into ice. When wind or solar radiation makes a thin film of ice on the surface this film may grow in thickness at the expense of the snow about it. The explorers even found that such a film could grow after it had been covered over with fresh snow; but it had its inception at the surface and would mark the stratification of the snow. A glance at our diagram shows that such a system of blue bands would appear at the vertical end of the glacier as nearly horizontal lines, separated by ice containing more air; for blue bands are merely layers of ice free, or nearly free, of air. Only in exceptional cases does the ice of Antarctic glaciers suffer much contortion, so that the banding at the glaciers' ends is usually simple. The influence of solar radiation in originating the banding is shown by the fact that the banding is better developed as the latitude is lower. Clearly there will be a limit to this, a limit which apparently is not reached in Antarctica. In the lower parts of the larger Swiss glaciers the transformation has proceeded so far that the ice in general consists of large crystals, the blue banding has been obliterated, and the stratification has disappeared.

The explorers discuss the mechanism of the flow of the ice and accept Chamberlin's view (in part at least) that it depends on the movement of "mobile" molecules and is related to the growth of crystals.

Silt Bands

About thirty years ago Chamberlin brought prominently to the attention of glacialists the vertical ends and sides of the glaciers of northern Greenland and the system of silt bands that appeared on these faces. He interpreted the bands as material picked up from the bed and brought into their present position by a series of shears, the successive layers of the glacier slipping over those underlying them. He actually saw one place where ground moraine was being incorporated into the ice; and Case made some

experiments that showed this was possible.[3] But the bands produced in this way were materially different from the systematic series. The Antarctic explorers found precisely similar series of bands in the Antarctic glaciers and made important observations which, I think, offer an entirely satisfactory explanation. They found that banks of drifted snow were in many cases made up of layers separated by silt bands, and the edges of the banks weathered like the ends of the glaciers. That the silt bands represented merely dust blown upon the surface of the snow was confirmed by the presence of penguin feathers and dead seaweed. On the eastern side of Robertson Bay (just west of Cape Adare), where the easily weathered volcanic rocks furnished large quantities of finely disintegrated rock to the winds, the bands were highly developed in drifts and glaciers; and on the western side of the Bay, where the rocks were much harder, the bands were less prominent.

Owing to the varying directions of the winds, the surface of the snow-banks was often carved into very irregular forms upon which were deposited more dust and more snow, showing marked unconformities and giving the appearance of contorted movements, which had not taken place. The confident conclusion of the explorers that the silt bands originate in dust blown on the surface of the glacier is supported, as in the case of the blue bands, by a glance at our diagram, which shows that the strata will lie roughly parallel with the glacier's bed and that their edges at the terminal face will be roughly horizontal lines except where the ice has been tortured into contorted movements or broken through by many crevasses—and these accidents are not very common in the Antarctic. The many striking unconformities seen on the glaciers and on icebergs receive here their full explanation.

Some silt bands are ascribed to dust blown into a crevasse which afterward closed. A diagram represents the suture of such a closed crevasse as a straight line gradually becoming more and more inclined on account of the greater velocity of the upper layers of the glacier, but the diagram is not exactly correct. On account of the differential velocity the vertical suture would be changed into a curved line, concave upstream. It would appear as a curved line on the side wall of the glacier, nearly horizontal at the bottom, curving well up into the upper layers, and ending at the line of flow which originated at the surface where the crevasse was closed; if the suture intersected the end face of the glacier, not too near the base, it should dip into the ice at a fairly high angle. Nothing of this kind was reported. It should also cut across the silt bands that mark the stratification. This may be the explanation of the apparent but somewhat doubtful crossing of silt bands shown in Plates 150 and 163. If a glacier were

[3] T. C. Chamberlin: Recent Glacial Studies in Greenland, *Bull. Geol. Soc. of America*, Vol. 6, 1895, pp. 199–220.

Idem: Glacial Studies in Greenland, *Journ. of Geol.*, Vol. 3, 1895, pp. 61–69, 198–218, 469–480, 565–582, 668–681, and 833–843.

E. C. Case: Experiments in Ice Motion, *ibid.*, Vol. 3, 1895, pp. 918–934.

greatly riven by crevasses, silt bands formed in this way would lose all regularity.

Chamberlin's authority leads the explorers to consider the possibility that the material of the lowest silt bands is incorporated ground moraine, though they recognize that the universality of these bands, their uniformity, and their similarity to the bands higher up in the ice offer special difficulties. I can see no necessity for this view; and it is to be noted that the explorers found no evidence that the layers of ice slipped along the silt bands. Our diagram shows that the bottom layers of the glacier originated at its head, where, in the case of cirques, much dust would accumulate. Moreover, the greater differential motion of ice near the glacier's bed would thin out the strata and bring the silt bands closer together. It must also be remembered that the ice near the bed is very old; the mean temperature of Antarctica is so low that the thinner glaciers would be frozen to their beds, making the velocity there so small that we must place the origin of this ice very far back in the past; is it not possible that when the silt of these bands was accumulated there may have been more disintegrated rock available?

Classification of Land-Ice Formations

The explorers have classified the Antarctic ice into four main types, namely, ice occurring in (1) the area of predominant supply, (2) the area of predominant movement, (3) the area of predominant wastage, and (4) the area of balanced forces. The ice of the high plateau, ice caps, and snowdrifts come under type 1; the valley portions of glaciers under type 2; the lower portions, piedmont ice, ice tongues, under type 3; and shelf ice under type 4. They have found this classification convenient for their descriptions; but it is not well adapted for the theory of glaciers. A large glacier may belong to all four types. For general purposes it would be better to divide a glacier into reservoir and dissipator, for each of these parts has distinct characteristics, and they are fundamentally related to the very existence of the glacier. Of course, the explorers recognize the relation, but they do not specifically emphasize it.

We have already discussed some of the types; and we shall now take up some others.

Piedmont Ice

Russell introduced the term, piedmont glacier, to describe the expanded ends of valley glaciers that coalesce at the foot of the mountains. The Malaspina Glacier is the classic example, and it is wholly dissipator. The two piedmont glaciers described in the Antarctic lie on shelves between the mountains and the sea; the explorers think they originated by the coalescence of the valley glaciers. This may be so, but the maps and the descriptions show that they no longer derive their supplies in this way but from snow accumulated on their surfaces. They lie wholly, or almost

wholly, in the region of supply; and they waste by melting in the sea water, by breaking off at their terminal cliffs, and, perhaps to a slight degree, by melting or sublimation at the surface. They only resemble Russell's type in their locations. Would it not be better to look upon them as individual and independent glaciers?[4]

Ice Tongues

Where an actively moving glacier reaches tidewater at a low gradient, it usually sends out a tongue which floats on the water to a distance of many miles. It stands up from a few feet to 200 feet above the water and is bounded on all sides by vertical cliffs. The calving of bergs on the sides naturally narrows the tongue as it advances so that it takes the shape of a triangle with the base at the coast line. Some of these tongues are of great size; the Shackleton tongue, on the northern coast, has a breadth at its base of nearly 200 miles and projects an equal distance beyond the coast. The Drygalski and the Nordenskjöld ice tongues project from the great scarp into the Ross Sea; and there are many smaller ones. The Mackaye ice tongue, in Granite Harbor, and the Erebus Bay ice tongue, on the southwest side of Ross Island, are each six or seven miles long; the former is about three miles wide, and the latter a little more than one mile. Their sides are nearly parallel. They owe their extension and shape, apparently, to their sheltered positions. The Mackaye tongue enters the head of the harbor, which, in winter at least, is entirely frozen over. Its movement was measured and found to be nearly three feet a day. The shores of the harbor are nearly parallel with the glacier tongue; and cracks, designated as shear cracks, occur in the fast ice (the frozen sea water), running from the shore to the tongue and pointing upstream at an angle of about 45°. These cracks all start from projecting points of the shore, and the explanation is simple. The fast ice is frozen to the shore and to the tongue. As the latter moves forward tensions and pressures are developed in the fast ice like those on the sides of valley glaciers, which produce the marginal crevasses. The greatest pressure is parallel to the direction of the cracks and forces the fast ice into pressure ridges at the shore. Beyond a projecting point the retreating shore line allows the ice to move on, thus starting a shear crack, and the tension at right angles to it may open it to a considerable width. The pressure ridges about the Erebus Bay ice tongue indicate a velocity comparable to that of the Mackaye.

Shelf Ice: Ross Barrier

In some parts of the Antarctic there are sheets of fairly level floating ice ending in vertical cliffs, and their surfaces are continually accumulating snow. Nordenskjöld called them shelf ice. The explorers explain them as due to the coalescence of floating glacier tongues, to the accumulation

[4] The explorers recognize these differences and adopt the name tentatively.

of snow on fast ice, or to a combination of the two processes. It is thus that the great Ross Barrier, the most notable example of them all, was developed during the advancing stages of the glacial cycle; and now, during the waning stages, it is gradually being destroyed. It is nourished by the great glaciers that pour into it on its landward sides and by the accumulation of snow on its surface, which we have seen amounts annually to something like 15 inches of snow of specific gravity 0.5. It is losing ice by the calving of icebergs from its face and perhaps by melting at its under surface in contact with the salt water. Its cliffs face the sea for a distance of some 400 miles, and it stretches nearly as far southward to the great scarp, thus covering a great gulf in the Antarctic continent. Soundings in front of the face show depths of 300 to 400 fathoms. Its surface is practically level, though characterized by many gentle undulations, which cause the cliffs at the face to vary in height from 6 to 160 feet above the sea. The movement of the old *dépôt* showed that it is advancing with a velocity, near its western border, of about 1500 feet a year; but there are no crevasses except near the borders and near the mouths of the glaciers. When the *Nimrod* was moored alongside the face, the ice was found to rise and fall with the tides; so that it seems fairly evident that the Barrier is afloat over all or nearly all its area.

The position of the face at present is not one of equilibrium. From 1841 to 1902 it has broken back about 25 miles; and, since the ice has advanced about 17 miles in the same period, we see that the ice has been broken off to a depth of about 42 miles, that is the calving of icebergs has been more than twice as great as the movement. For equilibrium the two must be equal; but it does not seem probable that the equilibrium would ever be stable; an increase of velocity would not cause a greater calving, nor would a change in the rate of calving affect the velocity, so that the position of the face must always be changing and must depend very largely on its previous history. It must at some time have extended considerably further north than it does now; how far we do not know.

The explorers think the rate of calving is largely influenced by the melting in contact with sea water. May not the frequency and violence of storms be a more important factor? The Barrier is capable of adjusting itself to the movement of the tides without calving; but the greater range of storm waves, and their shorter period, would seem to be particularly effective for calving. The long and narrow Erebus Bay tongue maintained itself, in its protected situation, almost unchanged from 1902 to 1911; but during an unusually severe blizzard in the latter year, nearly half its length broke off and floated away as a great iceberg. I do not believe either the Erebus Bay or the Mackaye tongue could survive if subjected to the storm waves of the northern coast.

Sponges, shells, and mirabilite (sodium sulphate) deposits were found in several places on the surface near the ends of glaciers. Their character and appearance negatived the idea that they had been dropped on the ice,

and Debenham[5] supposed that they had been incorporated into the ice at its under surface and been gradually brought to the upper surface by ablation above and by growth due to freezing below. The explorers accept this explanation, but it seems hardly compatible with melting at the under surface of the Ross Barrier. It would have required much more intense cold. The Barrier undoubtedly was larger in the past, and the ice at other parts of the shore may have extended farther out upon the ocean; but was the temperature any lower than it is now? Indeed, could it have been any lower? Are not present conditions such as to produce as low a temperature as we could ever expect on the earth?

The two forms, the floating glacier tongue and the floating shelf ice, are peculiar to the Antarctic; they are unknown elsewhere. The explorers, reasoning by elimination, reach the conclusion that the absence of such forms in the Arctic is due to the warmer summer temperatures of the sea water there accompanied by more rapid melting and more rapid calving. There is another difference which was not noticed in this connection, namely, that the Greenland icebergs calve from the dissipator, where the ice has a high density, nearly 0.9, and is made up of glacier grains; the Antarctic icebergs calve from the reservoir and are made up largely of snow ice of lower density. Drygalski[6] has described the formation of a large berg at the end of the Great Karajak Glacier. His observations indicate that the glacier, progressing down a gentle slope, forces the end into the water to a lower level than the natural level of flotation and that the buoyancy of the water at last breaks it off. It then rises to the proper level and floats away. The explorers of Antarctica describe the continual accumulation of snow on the many ice tongues and on the shelf ice, and the melting at the under surface, until at their outer ends the whole thickness may consist of snow ice only. The stratification is shown primarily by the layers containing different amounts of air. Many of the large icebergs that have tilted show that their lower layers consist of this snow ice. The rise and fall of the ice with the tides show that it is flexible enough to adjust itself to the proper level of flotation quite rapidly. May not this flexibility, which does not seem to be shared by the Greenland ice, account for the existence of ice tongues and shelf ice in the Antarctic? And may not the greater flexibility be due to the less compact and less crystallized ice of the south?

Geologic Climates of Antarctica

An examination of the rocks, the fossils, and especially the paleobotany of Antarctica brought out pretty clearly that before the Tertiary the climate of the region was decidedly mild. Glaciers may have existed at times but apparently did not attain any great expansion. During the

[5] Frank Debenham: A New Mode of Transportation by Ice: The Raised Marine Muds of South Victoria Land (Antarctica), *Quart. Journ. Geol. Soc.*, Vol. 75, 1919, pp. 51–76.

[6] Erich von Drygalski: Grönland-Expedition der Gesellschaft für Erdkunde zu Berlin, 1891–1893, 2 vols., Berlin, 1897: reference in Vol. 1, pp. 391–392.

Permo carboniferous glacial period of lands in the southern hemisphere Antarctica seems to have enjoyed a temperate climate. There are some unsatisfactory indications of refrigeration in the Eocene; but it was not until the Pliocene that great ice sheets were developed; and they have continued, without clear evidence of interglacial periods, until the present day. As the explorers conclude, "glacial conditions have been the exception and not the rule in Antarctica." They place the time of maximum glaciation in the Pleistocene and bring forward much evidence showing the recent rapid dwindling of the ice. High level moraines and erratics have been found several hundred, and in cases one or two thousand, feet above the present ice in their neighborhood. Dry Valley, once filled with ice, is now quite bare; the same is true of other places. That the retreat is still in full swing is shown by the moraine-covered stagnant ice on the side of Koettlitz Glacier to a height of a thousand feet and by the remains of piedmont glaciers cut off from any supply and gradually disappearing. The retreat of Ross Barrier since Ross's visit in 1841 is also striking.

In discussing the cause of ice ages the author (Wright) has, without reaching any definite conclusion, been led pretty far afield; but this may be necessary, for certainly no convincing explanation of ice ages has yet been offered.

The volume on "Glaciology" is full of interesting and important observations and deserves the careful study of glacialists. I have been obliged to pass by much and to confine myself almost entirely to observations bearing directly on the theory of glaciers. The Antarctic observations do not conflict with the theory as generally accepted; they throw light on some questions, especially concerning the reservoir, that have been matters of controversy; and they describe characteristics peculiar to climatic conditions unknown in other parts of the world.

THE TERRITORIAL ORGANIZATION OF THE SOVIET POWER, 1924

By Robert F. Kelley
U. S. Department of State

The early part of the present year witnessed the completion of the territorial reorganization of the Soviet power which was entered upon in December, 1922, by the conclusion of a treaty between the four so-called Soviet Republics, known as the Russian Socialist Federated Soviet Republic, the White Russian Socialist Soviet Republic, the Ukrainian Socialist Soviet Republic, and the Trans-Caucasian Socialist Federated Soviet Republic, creating a new international entity to be known as the Union of Soviet Socialist Republics. The relations between the four States of the Union are defined by a Constitution promulgated on July 6, 1923, and definitively confirmed by the Second Federal Congress of Soviets on January 31, 1924. Prior to the creation of this new entity the territories of the former Russian Empire were occupied by a number of theoretically independent political units—the Russian Socialist Federated Soviet Republic, the Ukraine Socialist Soviet Republic, the Socialist Soviet Republic of White Russia, the Socialist Soviet Republic of Azerbaijan, the Socialist Soviet Republic of Armenia, the Socialist Soviet Republic of Georgia, the Far Eastern Republic, the Khivan People's Soviet Republic, and the Bukharan People's Soviet Republic.

The center of this group was the Russian Socialist Federated Soviet Republic, which, while formally recognizing the independence of the various Soviet republics, effectively directed and controlled the foreign policy and main lines of internal development of the several states. Azerbaijan, Georgia, White Russia, and the Ukraine were bound to Soviet Russia by treaties of military economic alliance, providing for the unification of various departments of the respective governments—Foreign Trade, Finance, Army and Navy, Means of Communication, Post and Telegraph, Labor, etc. With the Far Eastern Republic there existed merely an economic alliance, and with Armenia there existed an agreement introducing the financial system and regulations of Soviet Russia into Armenia. With Bukhara and Khiva, Soviet Russia had concluded simply treaties of alliance which made no provision for unification of governmental organs. It is to be noted that each of these states conducted its own foreign relations. At the time of the Genoa Conference (1922), for instance, a protocol was drawn up between Soviet Russia on the one side, and Azerbaijan, Armenia, White Russia, Bukhara, Georgia, the Far Eastern Republic, Ukraine, and Khiva on the other, authorizing Soviet Russia to represent and defend their interests at the European Economic Conference. The Constitu-

tion of July 6, 1923, consecrates this supremacy of Moscow and attempts to create a systematic organization in which the relations between the various Soviet States are carefully defined. A single international entity is thereby created, which the Bolshevik leaders believe can more effectively further Soviet interests than the several quasi-independent units that had existed hitherto. Thus from one point of view the creation of the Soviet Union may be considered as marking the reintegration of the various parts of the former Russian Empire, which had tended to escape from the control of Moscow during the period of civil war. On the other hand, it represents the creation of a form of political organization best adapted in the eyes of the Bolshevik leaders to the realization of their aims in the future. Admission to the Union, as the Preamble of the Constitution states, is "open to all Socialist Soviet Republics such as are now existing and such as shall arise in future," and the new Federal state is declared to be a decisive step towards the "union of the toilers of all countries into one world Soviet Socialist Republic."

The present international entity, therefore, is the Union of Soviet Socialist Republics, not Russia, nor the Russian Socialist Federated Soviet Republic.[1] The word "Russia" in so far as it is used by Soviet writers is restricted to the activities of the Russian Socialist Federated Soviet Republic, which is one of the component states of the Union; the Bolsheviks are very careful not to apply it when referring to the activities of the Soviet Power. The Soviet Union, as we have seen, is composed of four constituent republics. These in turn are composed of subordinate ethnic units,[2] all of which have representation in the Soviet of Nationalities, the upper chamber of the Federal Central Executive Committee, the supreme political authority in sessions between the Federal Congresses of Soviets. The first Soviet of Nationalities, elected on February 2, 1924, consists of one hundred members comprising five delegates each from six constituent republics, five delegates each from eleven autonomous republics, one delegate each from ten autonomous regions, and one delegate each from five autonomous areas in the Caucasus.

Russian Socialist Federated Soviet Republic (1–22)[3]

The Russian Socialist Federated Soviet Republic, which includes by far the largest part of the former Russian Empire, is the largest state in the Union, having an area of about 7,920,000 square miles with a population of about 97,000,000. Soviet Russia is composed of two groups of territorial subdivisions—provinces (1) on the one hand and, on the other, autonomous areas designated either as republics or regions (*oblasti*) with a certain

[1] The word "Russian" was erroneously inserted in the name as given in the *Geographical Review*, Vol. 14, 1924, p. 273.—Edit. Note.

[2] For a brief description of the principal ethnic stocks of European Russia in relation to the political subdivisions of Soviet Russia of 1923, see the *Geographical Review*, Vol. 14, 1924, pp. 270–274.

[3] Numbers in parenthesis correspond with numbers on maps, Figures 1 and 2.

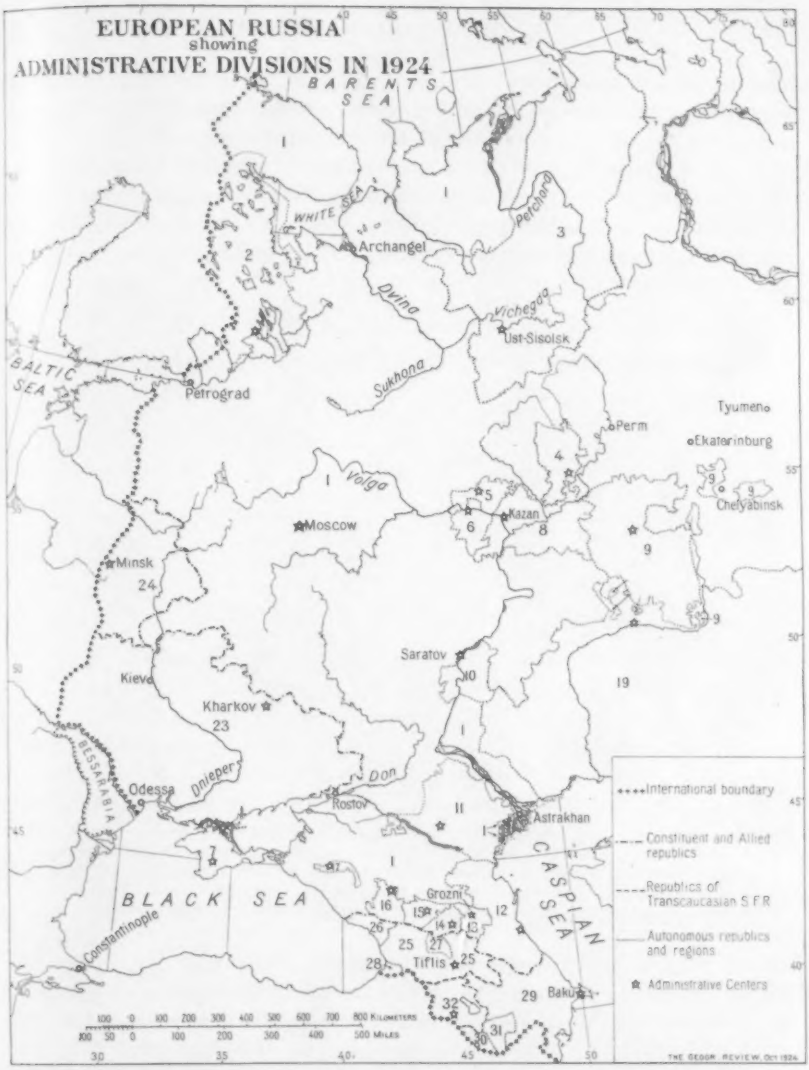

FIG. 1—Map of European Russia showing political subdivisions in 1924. 1–17 incl., Russian Socialist Federated Soviet Republic: 1, part of R. S. F. S. R. subdivided into provinces; 2–17 incl., autonomous republics and autonomous regions (*oblasti*) of the R. S. F. S. R. as follows: 2, Karelian Republic; 3, Ziryan (Komi) Region; 4, Votyak Region; 5, Mari (Cheremiss) Region; 6, Chuvash Region; 7, Crimean Republic; 8, Tatar Republic; 9, Bashkir Republic; 10, Republic of the Volga Germans; 11, Kalmuck Region; 12, Daghestan Republic; 13, Chechen Region; 14, Mountain (*Gorskaya*) Republic; 15, Kabardino-Balkar Region; 16, Karachaevo-Cherkess Region; 17, Cherkess-Adighé Region. 23, Ukrainian Socialist Soviet Republic. 24, White Russian Socialist Soviet Republic. 25–32 incl., Trans-Caucasian Socialist Federated Soviet Republic. 25–28 incl., Georgian Socialist Soviet Republic, comprising: 25, Georgian S. S. R. proper; 26–28 incl., autonomous republics and autonomous regions of the Georgian S. S. R. as follows: 26, Abkhazian Republic; 27, South Osetian Region; 28, Adzharian Republic. 29–31 incl., Azerbaijan S. S. R., comprising: 29, Azerbaijan S. S. R. proper; 30, Autonomous Nakhichevan S. S. R.; 31, Autonomous Region of Karabagh. 32, Armenian S. S. R.

measure of self-government (2–22). The part of Soviet Russia that is divided into provinces is primarily the part inhabited by the Great Russian population, and the provinces represent administrative units by which the territory is directly administered by the Central Government at Moscow. There are forty-seven provinces, of which forty are classified as falling within European Russia and seven as falling within Asiatic Russia.[4] In addition to these forty-seven provinces there exists the so-called Far

FIG. 2—Map of Asiatic Russia showing political subdivisions in 1924. 1, 18–22, Russian Socialist Federated Soviet Republic; 1, part of R. S. F. S. R. divided into provinces; 18–22 incl., autonomous republics and autonomous regions (*oblasti*) of the R. S. F. S. R. as follows: 18, Yakut Republic; 19, Kirghiz Republic; 20, Turkestan Republic; 21, Oirat Region; 22, Buryat-Mongol Republic. 33, Khivan People's Soviet Republic. 34, Bukharan People's Soviet Republic.

Eastern Region, which comprises most of the territory of the former Far Eastern Republic. This region at present is subdivided into four provinces, one of which, the Maritime Province, includes the northern part of the Island of Sakhalin, which is now occupied by the Japanese. The Far Eastern Region is an integral part of the Russian Soviet Republic. The association of the four provinces into a larger administrative union in this case does not represent the formation of a national unit but is rather due to the peculiar interests and special conditions existing in those areas formerly comprising the Far Eastern Republic.

The territories of the so-called Russian Soviet Republic that have certain

[4] European Russia is eventually to be reorganized into twelve "economic regions." Two of these are at present in process of creation—the Ural Region and the Southeast Region. The Ural Region includes the former Perm, Ekaterinburg, Chelyabinsk, and Tyumen provinces; the Southeast Region is to include the Don and Kuban regions, the Ter and Stavropol provinces, the city of Grozni, the Kabardino-Balkar, Karachaevo-Cherkess, Cherkess-Adighé, and Chechen autonomous regions, with capital at Rostov. [See *Geogr. Rev.*, Vol. 14, 1924, pp. 475–476.—EDIT.]

rights of self-government (2–22) fall into two groups, autonomous republics and autonomous regions. An autonomous region is simply an area inhabited by a certain nationality, organized out of one or several former provinces into a single unit with a provincial system of administration. It represents an attempt to bring people belonging to the same nationality into a single administrative unit that to all intents and purposes is similar to a "province," the term applied to the subdivisions of the area occupied by the Great Russian race. There are at present ten autonomous regions, all of which, except one, fall within the limits of European Russia.

Region (Oblast)	*Administrative Center*
Chuvash Region (6)	Cheboksari
Votyak Region (4)	Izhevsk
Kalmuck Region (11)	Ellista
Mari Region (5)	Krasnokokshaisk
Ziryan (Komi) Region (3)	Ust-Sisolsk
Kabardino-Balkar Region (15)	Nalchik
Karachaevo-Cherkess Region (16)	Batalpashinsk
Cherkess-Adighé Region (17)	Tokhtomukai
Chechen Region (13)	Grozni
Oirat Region (21)	Ulala

Each of these regions has one representative in the Soviet of Nationalities. The autonomous regions are administered by regional executive committees, elected by the Regional Congress of Soviets.

Nationalities more advanced in the eyes of the Soviet Power are organized into autonomous republics and enjoy a larger measure of self-government. There are at present eleven autonomous socialist soviet republics within the Russian Soviet Republic, of which seven are in European Russia and four in Asiatic Russia.

Republic	*Administrative Center*
Bashkir Republic (9)	Ufa
Tatar Republic (8)	Kazan
Daghestan Republic (12)	Buinaksk
Mountain (*Gorskaya*) Republic (14)	Vladikavkaz
Crimean Republic (7)	Simferopol
Karelian Republic (2)	Petrozavodsk
Republic of the Volga Germans (10)	Pokrovsk
Kirghiz Republic (19)	Orenburg
Turkestan Republic (20)	Tashkent
Yakut Republic (18)	Yakutsk
Buryat-Mongol Republic (22)	Verkneudinsk

Each of these republics has five representatives in the Soviet of Nationalities. The administration of the republics, according to the Constitution of the Russian Soviet Republic, consists of local Soviets, their congresses and executive committees, a Central Executive Committee, and a Soviet of People's Commissars.

White Russian Socialist Soviet Republic (24)

The second member of the Soviet Union, the White Russian Socialist Soviet Republic, comprises the six eastern districts of the former Minsk Province, eight districts of the former Vitebsk Province, six of the Homel Province, and one from the Smolensk Province. The population, of which over 75 per cent are White Russians, now numbers about 4,000,000. The capital is Minsk.

Ukrainian Socialist Soviet Republic (23)

The third member, the Ukrainian Socialist Soviet Republic, comprises the territories of the former Russian Empire in which the Ukrainians (Little Russians) predominate. The population of the Ukraine according to the census of 1920 is estimated at 26,000,000, of which 5,000,000 are urban. Of the country population 88 per cent are Ukrainian, while of the urban population only 34 per cent are Ukrainian, 29 per cent being Great Russian and 32 per cent Jews. The capital is Kharkov. The territory of the Ukrainian Republic is at present divided into nine provinces. In passing, it is important to notice that Bessarabia is still considered as a province of the Ukraine, although now occupied by the Rumanians.

Trans-Caucasian Socialist Federated Soviet Republic (25–32)

The fourth member of the Union is the Trans-Caucasian Socialist Federated Soviet Republic, which itself is a federation of three constituent republics established by a treaty signed on March 12, 1922, by the Socialist Soviet Republics of Azerbaijan, Armenia, and Georgia. A constitution of the Federated Republic was elaborated and confirmed by the First Trans-Caucasian Congréss of Soviets on December 13, 1922. The organization of the federal government is modeled on that of Soviet Russia. The capital is Tiflis. The government of the Trans-Caucasian Socialist Federated Soviet Republic has not as yet been centralized to the same extent as that of Soviet Russia, and the constituent republics, Azerbaijan, Armenia, and Georgia, still retain a large measure of genuine independence.

The Azerbaijan Socialist Soviet Republic (29–31) includes the former Baku Province and a large part of the Elizavetpol Province and adjoining districts. Its population is approximately 2,000,000, 75 per cent of whom are Azerbaijan Turko-Tatars. The capital of the republic is Baku. It comprises two autonomous areas, which are represented by one delegate each in the Soviet of Nationalities, the Autonomous Nakhichevan Republic (30) and the Autonomous Region of Karabagh (31).

The Armenian Socialist Soviet Republic (32) includes portions of the former Erivan, Alexandropol, and Elizavetpol provinces. The population numbers 1,200,000 and is 95 per cent Armenian. The capital is Erivan.

The Georgian Socialist Soviet Republic (25–28) includes most of the former provinces of Tiflis and Kutais and has a population of about

2,400,000, of whom about 80 per cent are Georgians. The capital is Tiflis. It comprises three autonomous areas, each of which has one representative in the Soviet of Nationalities; the autonomous Abkhazian Socialist Soviet Republic (26), which comprises six districts of the former province of Sukhum, the autonomous Adzharian Socialist Soviet Republic (28), which comprises the former Batum Province, and the autonomous South Osetian Region (27), which comprises the mountain region northwest of Tiflis inhabited by the Osets.

Other Territories

In addition to the above areas, which form a constituent part of the Soviet Union, there are three other regions standing in very close relation to the Soviet régime although not forming an integral part of the Union of Soviet Republics. Two of these states, the Khivan People's Soviet Republic (33) and the Bukharan People's Soviet Republic (34), are bound to the Soviet Union by treaties of alliance. Khiva has a population of about 1,000,000, of which 50 per cent are Uzbegs, 30 per cent Turkomans, and 15 per cent Kirghiz. Bukhara is considerably larger, having a population of about 3,000,000, of whom 80 per cent are Uzbegs, 6–7 per cent Kirghiz, and 7–8 per cent Turkomans. Both these states have entered into a customs union with Soviet Russia and have agreed to grant concessions to foreign states and individuals only with the approval of the Russian Soviet Republic. The third state in this category is Mongolia, which concluded an agreement with the Russian Soviet Republic on November 5, 1921, whereby the Russian Soviet Republic recognized the People's Government of Mongolia as the only legal government. At present Urga, the seat of the Mongolian Government, and other strategic points are occupied by Soviet troops.

PRESENT STATUS OF INTERNATIONAL BOUNDARIES IN SOUTH AMERICA

By Raye R. Platt

The past quarter of a century has witnessed much progress in the definition and demarcation of the international boundary lines between the republics of South America as the geographical features have become better known. At the beginning of this century the boundary disputes of major importance involved seven great areas. Of these, three—the Venezuela-Colombia, the Peru-Bolivia, and the Argentine-Chile—have been settled. Of the four remaining, the Argentine-Bolivia dispute has been reduced to one of minor proportions; Colombia and Ecuador have arrived at an amicable settlement of their common share in the long-standing Peru-Ecuador-Colombia dispute; and the Chile-Peru dispute is at present in process of adjustment at Washington, the President of the United States acting as arbitrator. There remain still, without prospect of early settlement, only the Peru-Ecuador and the Bolivia-Paraguay disputes.

Many of the boundaries, however, are still undemarcated. Of approximately 15,000 miles of international boundary in South America about 8000 miles have been demarcated, while the disputed areas still involve nearly 2500 miles of boundary yet to be defined. Also many sections which may be considered as demarcated have been marked only with a few pillars in critical places, with the result that wherever in the future a frontier area between such pillars becomes sufficiently populated as to necessitate a precise location of the line the boundary question for such a section will of necessity be reopened. It follows, therefore, that a boundary can only be completely and finally settled when the area involved has been accurately triangulated and topographically surveyed and the results plotted on maps acceptable to all the parties concerned.

In the following notes boundaries whose land sections are demarcated and whose waterway boundaries are defined according to official surveys or surveys accepted as official are accepted as completely demarcated. However, such a designation has obvious limitations. With the greater commercial development of the South American realm it is certain that the problem of the sovereignty of natural resources which may underlie river channels will arise again and again.

Colombia-Panama

By the treaty of April 6, 1914, between Colombia and the United States, Colombia recognized Panama as an independent nation and agreed that the boundary between Colombia and Panama should be the boundary between

FIG. 1—Map showing the status of international boundaries in South America. Numbers have reference to areas in dispute thus: 1, Peru-Ecuador; 2, Peru-Colombia; 3, Colombia-Brazil; 4, Chile-Peru; 5 and 6, major disputed areas between Argentine Republic and Bolivia; 7, Bolivia-Paraguay. The scale of the map is 1 : 47,500,000.

the Colombian provinces of Cauca and Panama as defined by the Colombian Law of June 9, 1855.[1] Panama, however, was not a party to this treaty and had no diplomatic relations with Colombia until May 8, 1924, when at the invitation of the Secretary of State of the United States the ministers to the United States from Colombia and Panama met and signed an agreement which provided for a boundary convention and treaty of peace and friendship. Until such time as the decision of this convention is ratified by the two governments the boundary must be considered as undefined.

Colombia-Brazil

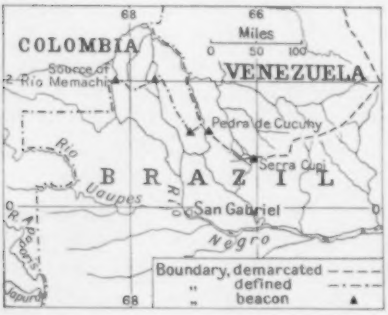

FIG. 2—Map showing Brazil-Colombia boundary defined by the Treaty of Bogotá, April 24, 1907. The boundary beacons are those set up by the joint Venezuela-Brazil commission in 1879 and 1880. Scale of map 1 : 12,000,000.

By the Treaty of Bogotá of April 24, 1907, the boundary between Colombia and Brazil from the mouth of the Rio Apaporis in the Rio Japurá or Caquetá to a point on the island of San José in the Rio Negro opposite Pedra de Cucuhy was defined.[2] Three monuments set up by the joint Venezuela-Brazil boundary commission in 1879 and 1880 mark the section of this line which lies between the source of the Rio Memachi and San José island. All of this section is now included in the Colombia-Brazil boundary, and since Colombia was not a party to the erection of these monuments the entire line must be taken as undemarcated.

From the mouth of the Rio Apaporis southward to the mouth of the Rio Ambiyacu in the Rio Amazonas, defined by the Treaty of Bogotá of July 15, 1916, as the easternmost limit of the boundary between Colombia and Ecuador, is an area divided, by the Tabatinga-Rio Apaporis line of the Brazil-Peru treaties of 1851 and 1874, into two disputed sections. The section west of the Tabatinga-Rio Apaporis line is still in dispute between Peru and Colombia. Colombia was not a party to the treaties which defined this line and disputes the claim of Brazil to the area between the Rio Japurá and the Rio Amazonas from the Tabatinga-Rio Apaporis line eastward to the confluence of the Japurá with the Amazonas.[3] By the Brazil-Ecuador boundary treaty of May 6, 1904, Ecuador agreed that in case the Peru-Ecuador boundary dispute was settled in favor of Ecuador the boundary between Ecuador and Brazil should follow the line agreed

[1] Informe del Ministerio de Relaciones Exteriores, Bogotá, 1914, p. 151.

[2] Thiers Fleming: Limites e superficie do Brazil e seus Estados, Rio de Janeiro, 1918, pp. 123 and 124. See also Demetrio Salamanca T.: La Amazonia Colombiana: Estudio geográfico, histórico y jurídico en defensa del derecho territorial de Colombia, Vol. 1, Bogotá, 1916, pp. 246–247.

[3] Salamanca T., *op. cit.*, pp. 479 and 854.

upon between Brazil and Peru by the Convention of Lima of October 23, 1851, and the modifications specified by the subsequent agreement signed between Brazil and Peru at Lima, February 11, 1874.[4] Ecuador is therefore no longer a party to any settlement of the boundary from the mouth of the Rio Apaporis to the Rio Ambiyacu which will follow the adjustment of the counter claims of Peru and Colombia in this region.

Colombia-Ecuador

By the Treaty of Bogotá of July 15, 1916, the boundary between Colombia and Ecuador from the mouth of the Rio Mataje in the Pacific Ocean to the mouth of the Rio Ambiyacu in the Amazon River was defined. As set forth by the concluding session of the joint boundary commission at Cartagena, July 9, 1919, the boundary from the mouth of the Rio Mataje to the most westerly point of the watershed between the Rio Putumayo and the Rio Napo was surveyed by precise triangulation and by measurements adjusted to points located astronomically by telegraphic time signals from Quito and was marked by monuments.[5] The joint commission found that at many points the definition of the boundary had been based upon inadequate knowledge of the topography. Important modifications were found necessary, and agreement in each case was arrived at by the commission. A gap on the Rio San Juan was not surveyed, there being apparently no doubt as to the position of the boundary in this section.

From the eastern end of the demarcated section the line is defined as following the divide between the Rio Putumayo and the Rio Napo to the source of the Rio Pastaza, which is considered as the principal head stream of the Rio Ambiyacu. Thence the line follows the Rio Pastaza and the Rio Ambiyacu to the Amazon. All of this section falls within the area claimed by Peru, and its final definition must await the settlement of the Peru-Ecuador dispute.

Colombia-Venezuela

By an arbitration agreement signed at Caracas, September 14, 1881, the long-standing boundary dispute between Colombia and Venezuela was referred to the Spanish Crown for settlement. At Paris, February 15, 1886, an act was signed by representatives of the two countries which repeated the agreement of 1881. On March 16, 1891, the Spanish Crown rendered its decision, and on July 6, 1891, the Colombian minister at Caracas suggested the appointment of a mixed commission to carry out the award of arbitration, inasmuch as part of the boundary as defined did not follow natural frontiers. After some delay a convention was signed in Caracas, December 30, 1898, establishing a mixed commission. Surveys were made of several sections of the boundary in 1900–1901, but, in view of many

[4] *Ibid.*, p. 253.

[5] Arreglo de límites entre las Repúblicas del Ecuador y Colombia, documentos oficiales, Quito, 1920. See also *Geogr. Rev.*, Vol. 11, 1921, pp. 296 and 297.

important disagreements, a convention was signed at Bogotá, November 3, 1916, by which it was agreed to submit the execution of the Spanish award to the Swiss Federal Council.

On March 24, 1922, the Swiss Council presented its decision which provided for a committee of Swiss experts who should survey and examine those sections still in dispute and rectify positions located by the joint Venezuelan-Colombian commission in 1900 and 1901. The Swiss experts were to complete their mission by December 31, 1924. Meanwhile the two governments were instructed to occupy such areas as had been accepted by the mixed commission in 1900 and 1901.[6]

Venezuela-Brazil

The Treaty of Caracas of May 5, 1859, first defined the Venezuela-Brazil frontier. According to its provisions a mixed commission later surveyed this boundary from Pedra de Cucuhy to Serra Cupi, or Cupuy. In addition the commission surveyed the Rio Negro and its tributaries from the Pedra de Cucuhy to a monument erected at the principal source of the Rio Memachi; territory then claimed by Venezuela but since assigned to Colombia and forming an item in the Colombia-Brazil Treaty of 1907. The only precisely demarcated section of the line which now divides Venezuela and Brazil is a small section (10,675 meters) of the straight line from the Falls of the Maturacá Canal to the Serra Cupi. In 1882 and 1884 the remainder of the line was located and marked in a few critical places by a Brazilian commission. By the Accordo of 1900 the frontier was again defined, and in 1915 protocols were signed at Caracas accepting the line between Pedra de Cucuhy and Serra Cupi as located in 1880 and referring the remainder, which had been located by the Brazilian commission in 1882 and 1884, to a mixed commission for verification. February 29, 1912, another protocol was signed at Caracas; and, in accordance with its terms, in December, 1914, and January, 1915, Pedra de Cucuhy was located by astronomical observations, and four monuments were set up on the line between Pedra de Cucuhy and the Falls of Maturacá.[7]

Venezuela-British Guiana

The boundary between British Guiana and Venezuela was defined by an award of the International Arbitration Court at Paris in 1899.[8] Demarca-

[6] Arbitrage entre la Colombie et le Vénézuéla: Sentence arbitrale du Conseil Fédéral Suisse sur diverses questions de limites pendantes entre la Colombie et le Vénézuéla, Berne, 24 Mars, 1922, Neuchatel, 1922. See also H. Case Wilcox: An Exploration of the Rio de Oro, Colombia-Venezuela, *Geogr. Rev.*, Vol. 11, 1921, pp. 372–383; reference on p. 372, footnote 2.

On July 10 of this year the American Geographical Society was informed by Dr. Alfredo Jahn of Caracas, Venezuela, that the commission of Swiss experts had completed its work and returned to Europe. With the exception of an area of about 150 square miles along the boundary in the vicinity of Cúcuta the Swiss commission did no surveying work but accepted the work of the mixed commission of 1900 and 1901.

[7] Fleming, *op. cit.*, pp. 133–136. See also Libro Amarillo de Venezuela, Vol. 1, pp. 164–165, Vol. 2, pp. 384–387, Caracas, 1915.

[8] Grover Cleveland: The Venezuelan Boundary Controversy, Princeton and London, 1913.

tion was completed in 1900 except for the section of the boundary between the summit of Mt. Roraima and Wenenau Creek. A deviation for this section of the boundary from the definition of the award was suggested by the joint commission and accepted by the two governments. The line of deviation follows the watersheds separating the Coroni, Cuyuni, and Mazaruni Rivers. In 1914 it was agreed that a joint commission should again demarcate the boundary with permanent monuments. This demarcation was carried out in 1916 and 1917.[9]

Brazil-British Guiana

By decision of the King of Italy, June 6, 1904, and by subsequent direct agreement between the two governments, the boundary between Brazil and British Guiana was defined. One monument has been set up at the source of the Rio Ireng or Mahu. No precise surveys have been made of the land sections of the line.[10]

British Guiana-Dutch Guiana

By the Treaty of Paris of 1814 the Dutch government ceded to Great Britain her colonies of Demarara, Berbice, and Essequibo. Discussion respecting the boundary line between these colonies and the present Dutch colony has to do with the question whether the head stream of the Courentyn River, which formed part of the eastern boundary of the ceded Dutch colonies, was the Cutari or the New River.[11]

Brazil-Dutch Guiana

The boundary between Brazil and Dutch Guiana is defined by treaty of May 5, 1906, as following the divide between streams flowing to the Amazon and those flowing to the Atlantic Ocean from the source of the Courentyn River to the source of the Maroni. The line has not been demarcated.[12]

Dutch Guiana-French Guiana

According to an agreement signed in 1836 the Maroni River was declared to be the boundary between Dutch and French Guiana. The joint commission appointed under this agreement was unable, however, to decide as to whether the Awa River or the Topanahoni was the main head stream of the Maroni. The matter was referred to the Emperor of Russia who, in 1891, rendered a decision accepting the Awa as the main head stream. In 1905 claims to certain disputed territory between the upper Maroni and the Iteng Rivers were settled by agreement between France and the

[9] Libro Amarillo de Venezuela, pp. 602–612, Caracas, 1915; pp. 328–336, Caracas, 1916; pp. 572–582, Caracas, 1917; pp. 211–212, Caracas, 1918.

[10] Fleming, *op. cit.*, p. 124.

[11] See H. D. Benjamins: De grenzen van Suriname, *West-Indische Gids*, 1921, Vol. 2, pp. 333–350.

[12] Fleming, *op. cit.*, p. 124.

Netherlands. The question of gold exploitation on the upper Maroni was solved by giving alternate reaches of the river to the French and Dutch, respectively. The principal islands of the lower Maroni were assigned to France at this time. Inasmuch as the whole river has been surveyed and the line in disputed areas demarcated, the entire boundary may be accepted as demarcated.

Brazil-French Guiana

A decision of the President of the Swiss Confederation, December 1, 1900, defined the boundary between Brazil and French Guiana. Inasmuch as no official survey of the Oyapock River, which forms the greater part of the boundary, has been made and no precise survey of the divide from the source of Maroni River to the source of the Oyapock exists, the entire boundary must be considered undemarcated.[13]

Brazil-Uruguay

The boundary treaties of 1851 and 1852 defined the boundary between Brazil and Uruguay, and, by the Accordo of 1853, the rights of the two nations in the Lagôa Mirim, the Rio Jaguarão, and the Arroyo San Miguel were determined. In 1852 and 1859 a part of the boundary from the mouth of the Arroyo Chuy in the Atlantic Ocean to the town of Quarahy on the Rio Quarahy was surveyed and 162 monuments erected.[14] Since official surveys exist for the Rio Quarahy the entire line may be considered demarcated.

By the Boundary Treaty of 1909 Brazil and Uruguay determined to resurvey the boundary, and between 1909 and 1912 the two commissions that had been appointed completed the triangulation of a section from the southern point of Lagôa Mirim to the source of the Rio Jaguarão.[15]

Brazil-Argentine Republic

The frontiers of Brazil and the Argentine Republic were first defined by treaty in 1857. In February, 1895, the section between the Rio Uruguay and the Rio Iguassú was again defined by the award of the President of the United States.[16] Difficulties in the interpretation of this award were adjusted by the Treaty of September 6, 1898. Between November, 1900, and October, 1904, the entire frontier was demarcated by a mixed commission except for a short section of the Rio Quarahy near the island of Quarahy or Brazileira. An act of October 4, 1910, signed at Rio de Janeiro,

[13] Fleming, *op. cit.*, p. 125.

[14] *Ibid.*, pp. 127 and 128.

[15] See Rapport sur les travaux géodésiques éxécutés de 1912 à 1922 par le Service Géographique de l'Armée Uruguayane, Colonel P. Gros, Toulouse, 1923; and Notice sur quelques travaux géodésiques éxécutés par des officers de l'Armée Brésilienne, Rio de Janeiro, 1922.

[16] J. B. Moore: History and Digest of the International Arbitrations to Which the United States Has Been a Party, 6 vols., Washington, D. C., 1898; reference in Vol. 2, pp. 1969–2026.

assigned certain islands in the Rio Uruguay and the Rio Iguassú to Brazil and the Argentine Republic, respectively.[17]

Brazil-Paraguay

By treaty of January 9, 1872, and the protocol of January 7, 1874, the boundary between Brazil and Paraguay was defined. The demarcation of the line was completed between August, 1872, and October, 1874, except for a section between the mouth of the Rio Apa and the mouth of the river known as Bahia Negra. Final definition of this section must await the

FIG. 3—Map showing the Peru-Brazil boundary defined by the Velarde-Rio Branco Treaty, July 12, 1904, and the Madeira-Acre section of the Brazil-Bolivia boundary defined by the Treaty of Petropolis, February 6, 1907. Scale of map 1 : 12,000,000.

settlement of the dispute between Paraguay and Bolivia. In the Rio Paraguay all reaches of the river to the north and east were assigned to Brazil, and those to west and south to Paraguay. The island of Fecho dos Morros was given to Brazil.[18]

Brazil-Bolivia

A treaty signed in 1867 defined the boundary between Brazil and Bolivia, and a joint commission immediately set to work to demarcate the entire boundary. In 1871 and from 1875 to 1878 two joint commissions and a Brazilian commission completed the demarcation of the section from the mouth of the Bahia Negra to the confluence of the Mamoré and Beni Rivers. Peru protested against the definition of the line from the confluence of the Mamoré and Beni Rivers to the source of the Rio Javary on the ground that this section of the line as defined ran through territory to which Peru laid claim. Final agreement was not arrived at until the final

[17] La Frontera Argentina-Brasileña (Estudios y Demarcación General 1887–1904, Division de Límites Internacionales, Vol. 1), Buenos Aires, 1910, pp. 544–561.

[18] *Ibid.*, pp. 129 and 130.

demarcation of the Peru-Bolivia boundary in 1911–1913. In 1897 a Brazilian commission marked the source of the Rio Javary and located it by astronomical observations. In 1899 a joint commission was appointed to mark the Madeira-Javary frontier. Again in 1901 and 1902 a joint commission undertook to verify the location of the source of the Rio Javary but was stopped by the revolution in Acre.[19]

The line was defined anew by the Treaty of Petropolis of November 17, 1903, in which special emphasis was given to the definition of that section of the boundary between the Rio Madeira and the Peru-Bolivia boundary.[20] An agreement of February 6, 1907, provided for a joint commission to mark the frontier established by the Treaty of Petropolis, to explore the section between the monument known as Marco Quatro Irmãos and a monument located on the right bank of the Rio Turvo in 1875, and to explore the Rio Verde. All of this work was carried out with exception of (1) the section between the Rio Turvo and the source of the Rio Verde and (2) a section between the principal source of the Rio Rapirran (a tributary of the Abuná) and the source of the Arroyo Bahia (a tributary of the Acre). With the exception of the latter section the frontier from the Madeira to the Peruvian-Bolivian boundary was surveyed with considerable exactness. A large number of points were located by astronomical observations, and a great many heights were measured.[21]

Brazil-Peru

By treaty of October 23, 1851, it was agreed between Brazil and Peru that their common boundary from the hamlet of Tabatinga on the Amazon River northward should be by a direct line to the Rio Japurá, or Caquetá, opposite the mouth of the Rio Apaporis and southward from Tabatinga by the Rio Javary from its confluence with the Amazon River.[22] Joint commissions working in 1866, 1873, and 1877 demarcated this boundary from the source of the Rio Javary to the mouth of the Rio Apaporis and agreed to a slight modification of the line whereby it should for a short distance follow the channel of the Rio Iça. By treaty of May 6, 1904, Ecuador agreed to recognize as her common boundary with Brazil such part of the line established between Brazil and Peru by the treaty of 1851 as would fall to Ecuador in case the Peru-Ecuador dispute should be settled in Ecuador's favor. When in 1867 Brazil and Bolivia agreed as to the location of their common boundary Peru protested on the ground that the line as defined from the confluence of the Rio Beni and the Rio Mamoré to the source of the Rio Javary ran through a region in which Peru disputed both Bolivian and Brazilian claims. The subject was the matter of frequent

[19] *Ibid.*, pp. 131–132.

[20] Memorandum del Ministerio de Relaciones Exteriores, Lima, 1903, p. 28.

[21] Fleming, *op. cit.*, p. 134.

See also P. H. Fawcett: Survey Work on the Frontier between Bolivia and Brazil, *Geogr. Journ.*, Vol. 33, 1909, pp. 181–185; and Memoria de Relaciones Exteriores de Bolivia, La Paz, 1916, p. 13.

[22] J. B. Moore: Brazil and Peru Boundary Question, New York [1904], p. 19.

discussion until an agreement was signed July 12, 1904, whereby two areas in the upper Juruá and Purús Rivers were declared neutral zones pending a definitive settlement of the line. By the Velarde-Rio Branco Treaty of September 8, 1909, a final settlement was reached by which the line was located from the Peru-Bolivia boundary on the Rio Acre, still in dispute, to the source of the Rio Javary; Peru agreeing in her negotiations with Bolivia to recognize the accord reached by Brazil and Bolivia in the Treaty of Petropolis as to the Brazil-Bolivia boundary along the Acre.[23]

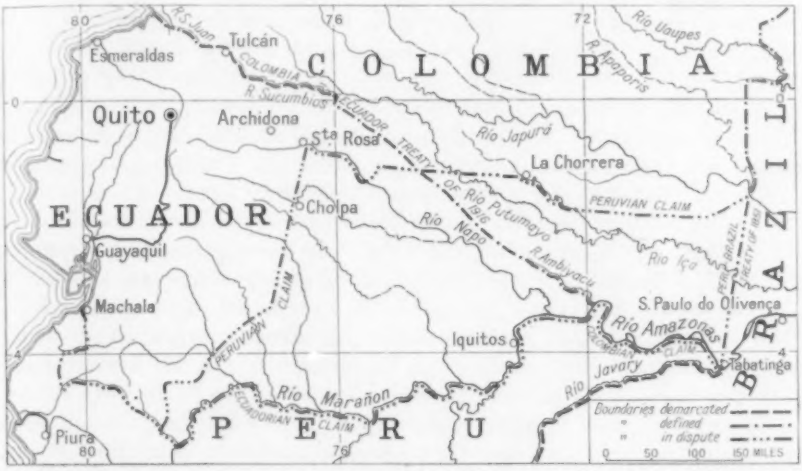

FIG. 4—Map showing the areas in dispute between Peru and Ecuador and Peru and Colombia, with the boundaries of the respective claims and the Colombia-Ecuador boundary defined by the Treaty of Bogotá, July 15, 1916. Scale of map 1 : 12,000,000.

Brazil-Ecuador

As mentioned above, a boundary treaty signed May 6, 1904, between Brazil and Ecuador agrees on the part of Ecuador that in case the dispute between Ecuador and Peru is decided in Ecuador's favor the boundary between Ecuador and Brazil shall be as established by the Convention of Lima of October 23, 1851, between Brazil and Peru and the modifications specified in the subsequent agreement signed between Brazil and Peru at Lima, February 11, 1874.[24] In case, therefore, Ecuador does win her claim and secure territory bounded by Brazil, her frontiers with Brazil will have been already defined and demarcated.

[23] In 1921 the American Geographical Society was notified by the Peruvian Embassy at Washington that a joint commission was engaged in surveying and demarcating the line from the Peru-Bolivia boundary demarcated in 1911–1913 to the source of the Rio Javary. A collection of unpublished maps received by the Society from the Lima Geographical Society since January, 1924, contains maps of surveys made by this joint commission in the upper Juruá and Purús. It is believed, however, that the work has not yet been completed.

[24] Salamanca T., *op. cit.*, Vol. 1, p. 243.

Ecuador-Peru

The Peruvian-Ecuadorean boundary dispute is one of the two disputes of major importance still to be settled in South America. It dates from the secession of the Republic of Ecuador from the triple confederation of Colombia, August 14, 1830. Ecuador claims that she is the heir of Colombia to the boundary between Colombia and Peru as defined by the Treaty of Guayaquil of September 22, 1829, and modified by the Pedemonte-Mosquera Protocol of 1830. Peru refuses to recognize this heirship, at least as far as the boundary is concerned, and claims a great region in the Oriente extending across territory claimed by Ecuador and into territory claimed by Colombia to a point in the Rio Japurá at the mouth of the Rio Apaporis.

Numerous treaties have been executed, but all have failed of ratification. Ecuador insists that arbitration or mediation of any sort is unnecessary since she stands ready to accept to the letter the Treaty of Guayaquil of 1829 and the Pedemonte-Mosquera Protocol of 1830. It was agreed, however, on August 1, 1887, by the Espinosa-Bonifaz Treaty to submit the question to the King of Spain. Ecuador, on learning that the decision of the King of Spain was to be in favor of Peru, withdrew from the arbitration. In the strained relations that followed, Brazil, the Argentine Republic, the United States, and the Hague Tribunal offered their services as mediators. Ecuador refused all offers on the ground that in the Treaty of 1829 lay the means for a settlement without outside help.[25] In 1911 the two governments agreed to make no further attacks on settlements established by the two countries in the Oriente pending a definite settlement of their counterclaims.

Peru-Chile

The history of the boundary controversy between Peru and Chile is too well known to require detailed description here. According to the Treaty of Ancón of October 20, 1883, Chile was to hold Tacna and Arica for ten years, at the end of which time a plebiscite was to be held to determine by vote the future sovereignty of the province. At the expiration of the first ten years and subsequently Chile progressively delayed the holding of the plebiscite. A protocol and supplementary act was signed at Washington, July 20, 1922, and ratified January 15, 1923, which provided for the submission by each country of its claims and supporting evidence to the President of the United States as mediator. On November 13, 1923, these claims and evidence were presented by both countries. According to latest information a two-months' extension of time was granted on April 13, 1924, for the submission of further evidence on application by the Chilean representatives and agreement by the Peruvian representatives.

[25] Pastoriza Flores: History of the Boundary Dispute between Ecuador and Peru, New York, 1921. See also *Geogr. Rev.*, Vol. 5, 1918, p. 327.

Peru-Bolivia

Officially, the boundary controversy between Peru and Bolivia begins with the recognition of the Republic of Bolivia by the Republic of Peru, May 18, 1826. The first boundary treaty signed by representatives of the two countries was the Treaty of Chuquisaca, November 15, 1826, by which Bolivia was to cede to Peru all her claims of sovereignty in Lake Titicaca, while maintaining to herself equal rights with Peru of navigation and fishing in the lake. In return Bolivia was to secure an addition to her littoral province from the eighteenth to the twenty-first parallel of latitude. The treaty proved unsatisfactory to both parties, and a second treaty was signed at Arequipa, November 8, 1831, which provided for a joint commission to make a map of the frontier regions in order that the changes and concessions necessary might be made with a minimum of detriment to the countries concerned. Bolivia rejected this treaty, and a third convention was signed at Cuzco on August 14, 1839, by which it was agreed to demarcate the boundary along natural barriers and to accept the Rio Desaguadero as a part of this natural boundary. Bolivia again objected not only because of the loss of certain provinces west of the Rio Desaguadero but also because the Rio Desaguadero was not considered a sufficiently strong international barrier.

Again in 1896 negotiations were opened at Sucre, and on July 21, 1897, it was agreed to give 60 days to the study of the problem and, in case of failure in arriving at an agreement, to submit the entire question to the Spanish Crown for arbitration. At the conference a suggested *modus vivendi* was presented, but no agreement was reached. Shortly afterward, in 1898, representatives met at Lima and agreed to appoint a joint commission to survey the frontier region, to study the line across Lake Titicaca, and to present a proposal for the settlement of all or part of the line. Six months were to be allotted to the work, and at the end of that time the Spanish Crown was to be asked to settle the question, basing its study on the location of the line of 1810 between the *audiencias* of Lima and Charcas. A revolution in Bolivia put an end to these negotiations.

By a treaty of arbitration, December 30, 1902, the Argentine Government was asked to study evidence submitted and decide the location of the ancient boundary between the *audiencias* of Lima and Charcas. By Article 2 of this treaty it was stated that the section of the boundary running from the line between the provinces of Tacna and Arica and the Bolivian province of Carangas to the Nevados de Palomani north of Lake Titicaca had already been defined and its demarcation provided for by a treaty of September 23, 1902. The Argentine Government, therefore, was to limit its work to the section north of the Nevados de Palomani.

The award was presented July 9, 1909. Bolivia objected to many details of the decision. Peru recognized the justice of many of these objections, and as a result a treaty was negotiated by direct accord September

17, 1909, by which the difficulties were adjusted to Bolivia's satisfaction. On February 2, 1911, both countries appointed boundary commissions, and in 1911–1913 the line from the mouth of the Arroyo Pachacili in the Rio Suches to the Rio Acre was surveyed and demarcated except for a section from the southerly end of the Cordillera de Ichocorpa between the Lanza and Tambopata Rivers to the confluence of the Rio Heath and the Rio Madre de Dios—a section surveyed by the Peruvian commission but left undemarcated because of the difficulties of the task.[26]

The section from the Rio Suches to the Chilean frontier still remains undemarcated.

Bolivia-Chile

At the close of the war of 1879–1883 Bolivia lost her littoral province of Antofagasta and all access to the Pacific Ocean except such as Chile would permit. The years from 1883 to 1904 saw many negotiations and treaties, none of which were effective until that of October 20, 1904, by which Bolivia definitely ceded to Chile her coastal territory and was granted an outlet to the sea by way of the Arica-La Paz railroad since constructed. The survey of the boundary was completed and the boundary demarcated and maps published in 1912. Bolivia, however, may still open the question again at any time in view of her contention that the treaty was forced upon her.[27]

Bolivia-Paraguay

The first of the important boundary treaties executed between Paraguay and Bolivia was that of October 15, 1879, which defined the northern limits of Paraguay in the Gran Chaco as the parallel of the mouth of the Rio Apa in the Rio Paraguay from the mouth of the Rio Apa to the point where that parallel cuts the Rio Pilcomayo. This treaty proved unsatisfactory to Paraguay whose claims extended as far north as to include the Bahia Negra.

A new treaty, the Treaty of Tamayo-Aceval of February 16, 1887, divided the disputed territory into three sections and recognized as belonging to Paraguay the section between the Rio Pilcomayo and the parallel of the mouth of the Rio Apa as far west as the sixty-third meridian from Greenwich. The second section, between the parallel of the mouth of the Rio Apa and the parallel which cuts the Rio Paraguay one Spanish league north of Fuerte Olimpo and extending as far west as the sixty-third meridian from Greenwich, was to be the subject of further negotiation. The third section, between the second section and the Bahia Negra, was to be given to Bolivia. This treaty expired unratified. On November 23, 1894, a new treaty was arranged which defined the boundary as a straight line from a

[26] Miguel Mercado M.: Historia internacional de Bolivia: Cuestiones de límites, Cochabamba, 1915, pp. 281–326.

See also Peru-Bolivia Boundary Commission, 1911–1913: Reports of the British Officers of the Peruvian Commission, Diplomatic Memoranda and Maps of the Boundary Zone, Cambridge, 1918.

[27] José Carrasco: Bolivia's Case for the League of Nations, London, 1920.

See also: Mercado M., *op. cit.*, pp. 191–280.

point three Spanish leagues north of Fuerte Olimpo to the principal course of the Rio Pilcomayo at 61° 28′ west of Greenwich. This treaty because it was considered "detrimental to the interests of Bolivia" was never submitted to the Bolivian Congress.[28]

In 1913 it was agreed between the two countries that all previously written agreements would be annulled and that an attempt would be made to settle the matter by direct negotiation. In case this failed recourse was to be had to arbitration.

FIG. 5—Map showing areas in dispute (1) between Bolivia and Paraguay and (2) between Bolivia and the Argentine Republic (Yacuiba and overlapping claims west of La Quiaca). Scale of map 1 : 12,000,000.

Bolivia-Argentine Republic

The first of the important treaties leading to a final settlement of boundary dispute between Bolivia and the Argentine Republic was the Treaty of Friendship, Commerce, and Navigation signed at Oruro, December 7, 1859. Bolivia did not ratify this treaty, and four more treaties or protocols were drawn up and rejected before the treaty of May 10, 1889, definitely located the boundary from the extreme northern limit of the Chile-Argentine boundary to the point where the twenty-second parallel cuts the Rio Pilcomayo. This treaty, by which Bolivia lost her claims in the Puna de Atacama and the Chaco Central but gained her claims in the province of Tarija, was ratified by the Argentine Republic November 12, 1891, and by Bolivia September 15, 1892.[29]

Commissions appointed to survey the boundary found that in a great many details the definition of the boundary had been based on inadequate

[28] Luis de Gásperi: Geografía del Paraguay, Buenos Aires, 1920, pp. 244–248. See also Mercado M., *op. cit.*, pp. 71–134.

[29] Mercado M., *op. cit.*, pp. 135–190.

or completely erroneous ideas of the topography of the region involved. For instance, in 1895 it was found that the Bolivian town of Yacuiba lay south of the twenty-second parallel in territory assigned to the Argentine Republic by the treaty. With a view to correcting errors in the original definition of the line, "rectifying protocols" were signed in 1898, 1902, and 1904, and the General Treaty of Arbitration on January 27, 1903. In 1909 a rupture in the diplomatic relations between Bolivia and the Argentine Republic took place as a result of the Argentine award in the Peru-Bolivia boundary dispute. Relations were renewed, however, in 1911, and the treaty of 1889 was again recognized and approved. On October 13, 1911, a protocol was signed and approved assigning Yacuiba as well as the towns of Esmoraca, Rosario, San Juan, San Antonio, and Guadalupe and the mountains of Moroco, Bonete, Azulejo, and San Antonio to the Argentine Republic.

In spite of the terms of the protocol Bolivia still insists that she has been the victim of an erroneous conception of the topography and the location of towns in the area between the Chilean frontier and the Rio Pilcomayo, and the Argentine Republic has made no arbitrary demand that the protocol of 1911 be carried out to the letter. Bolivia still maintains a customhouse at Yacuiba and has offered territory elsewhere in exchange. The Argentine Republic, on the other hand, has offered Bolivia territory on the west bank of the Rio Itau in exchange for Yacuiba.[30] At any rate both countries are anxious to settle the difficulty. Meanwhile, although the entire boundary has been demarcated, the monuments are considered as provisional only. The entire boundary, therefore, must still be taken as in dispute, except for the section along the Rio Pilcomayo to the twenty-second parallel and along this parallel to the crest of the Sierra de Ipaguazu, and the section from the confluence of Rio Tarija and the Rio Itau to the confluence of the Rio Lipeo and the Rio Bermejo.

Paraguay-Argentine Republic

The Boundary Treaty of February 3, 1876, defined the boundary between Paraguay and the Argentine Republic as following the principal channel of the Rio Paraná from the Brazilian-Argentine boundary to its confluence with the Rio Paraguay and thence by the main channel of the Paraguay to its confluence with the main channel of the Rio Pilcomayo. The region between the Rio Pilcomayo and the Bahia Negra was divided into two sections. Of these the northern, between the Rio Verde to the Bahia Negra, was recognized as belonging to Paraguay. The southern, between the Rio Verde and the Rio Pilcomayo, was to be the subject of further negotiations. By award of the President of the United States, November 12, 1878, the southern section was also given to Paraguay, and the Rio Pilcomayo was declared the boundary as far as the Bolivian fron-

[30] See La cuestion de límites pendiente con la Republic Argentina, Ministerio de Relaciones Exteriores, La Paz, 1922.

tier.[31] Although official surveys of the Rio Paraná and Rio Paraguay exist, as well as accepted surveys of the Rio Pilcomayo, the line cannot be considered completely demarcated until the boundary between Bolivia and Paraguay is defined and located.

Argentine Republic-Uruguay

Brazil and the United Provinces of the Rio de la Plata recognized the independence of Uruguay by the treaty of August 27, 1828, in which Great Britain acted as mediator.[32] The boundary between Uruguay and the Argentine Republic was defined as following the natural channel of the Rio Uruguay to its mouth in the Rio de la Plata and thence the northeastern bank of the Rio de la Plata. Uruguay now claims the median line of the La Plata as the boundary. Her claim includes control of the channel built and lighted by the Argentine Republic.[33] The two governments signed a convention April 11, 1918, providing for a triangulation of the Rio Uruguay and the estuary of the La Plata from the mouth of the Rio Cuareim to the mouth of the estuary. To date this triangulation has not been carried out, but the Military Geographical Institutes of the two countries have been designated to do the work.

Argentine Republic-Chile

The treaty of 1856 was the first important treaty having to do with the defining of the Chilean-Argentine boundary. This treaty proved unsatisfactory, and a new treaty was signed July 23, 1881. The northern part of the boundary, especially in the Puna de Atacama, still lacked precise definition. The discussion reached its height in 1892; and in March, 1893, representatives were appointed to a convention which on May 1, 1893, signed a "Protocol adicional y aclaratorio del Tratado de Límites de 1881." Chile once more protested against the definition of the northern part of the boundary as set forth in this protocol, and a second protocol was signed in September, 1895, which, however, did not settle the question. By the Compromise of April 17, 1896, the two countries agreed to ask the mediation of the Queen of England if direct agreement could not be reached. In 1896 the two countries seemed on the verge of war, but delegates were again appointed and the act of September 22, 1898, was signed. Other acts and notes followed, and in March, 1901, delegates were appointed to a tribunal of arbitration. In May, 1902, a general treaty of arbitration was signed and, in July, 1902, a supplementary act by which it was agreed to submit the whole dispute to the King of England for arbitration. Experts were appointed who studied the problem on the ground and drew up proto-

[31] Moore: History and Digest, Vol. 2, pp. 1923–1944.
[32] W. S. Robertson: Rise of the Spanish-American Republics, New York, 1918, p. 180.
[33] See the map (Fig. 280, p. 578) in Isaiah Bowman: The New World, Yonkers, 1921.

cols and acts defining the boundary in the disputed sections. The King of England rendered his award November 20, 1902. Boundary commissions were appointed to survey the debated sections of the line and set up pillars. The work of demarcation was completed in 1907.[34]

[34] La Frontera Argentino-Chilena (Documentos de la Demarcación, Oficina de Límites Internacionales, Vol. 2), Buenos Aires, 1908.

GEOGRAPHICAL RECORD

NORTH AMERICA

A Texan Study in Range Economics. "An Economic Study of a Typical Ranching Area on the Edwards Plateau of Texas" by Professor Youngblood (*Texas Agric. Exper. Sta. Bull. No. 297*, College Station, Brazos Co., Tex., 1922) is an important contribution to the study of land utilization that must form the basis of an adequate land policy. The broad objects of the study are to correct the impression that ranching is an "exploitive industry and that it is destined to pass away, and in part to aid in placing the grazing industry on a sound economic and social basis." Such a study is important to millions of people and affects a large part of the national domain. It has been estimated that there are in the United States 615,000,000 acres of permanent range land, or about 32.4 per cent of the total area. When there are added to this area parts of woodland and forest that are suitable for grazing, the percentage is raised to 45. In individual states in the West the matter is of still more importance. Of the total area of Texas 73.4 per cent is devoted to grazing, and only 18.6 per cent is classified as improved land and farms. Professor Youngblood's study advances the education of the public respecting the land requirements of successful ranching. The industry is peculiarly susceptible to the menace of too small units. Area of land alone has no significance in ranching. A distinction must be made between farm land and ranch land and the different grades of each. In the better farming area of Texas there are required from 80 to 160 acres to make a "family-sized farm." In the permanent ranching country there are required from 2560 to 12,800 acres to support one family.

Professor Youngblood has done a useful service in making his study realistic throughout. By confining the detailed field work to a single county (Sutton) we obtain a concrete picture of the industry and its difficulties. Especially interesting is the plan (p. 132) of Halbert's ranch showing subdivisions into fields, location of dirt tanks and rock tank, the disposition of sheds, roadways, corrals, troughs for salt or water, and the like. In all, 97 ranches were studied and many interesting statistics are given of the value of land, stock, headquarters buildings, and particular economic and engineering difficulties; for example, the water system, with its surface reservoirs, its deep wells, and pumping engines. On the economic side the matter of labor supply, the sale of the products, marketing conditions, and diversity of products are all brought into the discussion. The study is full of well-classified geographical material that will be especially valuable when a broader synthesis is undertaken of the western ranching country as a whole.

A Source of Data for Regional Survey: An Example from Texas. The colonization of the earth by man is along the line of least geographic resistance, but, as the process goes on, the resistance increases until a point is reached where it becomes necessary to remove opposition by artificial means. Today, in most countries, the white race within the pioneer belt is engaged in occupying the less suitable places by interference with nature. If a place shows itself desirable difficulties are overcome. But even in the process of removal deference is shown to the accidents of nature, and only the easiest adaptations are effected. Many attempts fail, and struggling little places give up the ghost and are deserted. The country accepts the settler or drives him away; the minor features of geography are determinants of the prosperity of communities.

The geographer looks to the regional survey movement for the best development of his line of inquiry. Regional survey, overlooking nothing, inevitably becomes intensely local. The broad view can show only the outstanding condition. The intimate view is necessary to reveal the cause of the condition. Final realization must come from an appreciation of local circumstances, which, in turn, must be gathered by the survey from the local resident. Hence the local contribution to the geographic understanding of places becomes a factor of the greatest importance. Meanwhile valuable material is being produced; but much of it must pass unseen by those who would discern its wider value, and it is forgotten.

An example has come to hand which we produce in the hope of encouraging perhaps a few interested persons to collect material of the kind. It is a newspaper article (Louella Sewell Cullom: Scyene, *The Texas Mesquiter*, Friday, April 18, 1924) dealing, unconsciously to the point, with the history of a small Texan village ten miles east of Dallas. The village of Scyene, in the early days, seems to have been one of those more or less evenly distributed small centers that focus the minor external economics of a region of scattered population. Dallas was another and no more, it seems, than an equal. Both villages had the customary delusions of ultimate greatness. But Dallas had its navigable river, whereas Scyene, being situated on black, waxy land, had only wretched roads and was quite inaccessible in rainy weather. The position was one that demanded a large town sooner or later. In 1868 ferryboats came up from Houston to Dallas, consequently Dallas now has something akin to greatness, while Scyene has only delusions. But it keeps them. It hoped for the salvation of the railroad; but, owing to the chance matter of a right of way, the Texas and Pacific line avoided the place by a mile in 1871, and Scyene dwindled. But the old stage road from Dallas to Kaufman ran through Scyene; and the village remembers, for automobiles are here. They require roads, and roads defer to geography. Scyene has recently found itself on a main road, State Highway No. 15, and anticipates growth. The ultimate fate of the village will probably be incorporation with Dallas after a thriving satellitic phase. Among other picturesque things Mrs. Cullom relates the origin of the name, and place names are always of interest to geography. The early residents picked a good name, Seine, that of the French river, and misspelt it. A younger generation, hopeful for the place, changed the form to a more high-sounding one.

It may be noted here that the magazine section of the Sunday issues of the *Dallas News* contains a page or so devoted to the origins of Texan place names.

This contribution is typical of the more intelligent rural press in many parts of the country. We suggest that the geography teachers in local schools have an opportunity to collect and file material of this kind. It is directly applicable to teaching if the course given have any vitality. A few good examples of this kind of local study are enough to illuminate a whole region. The school record of local history and geography has, if it were only realized, an enviable opportunity of giving valuable aid to the regional survey which must come sooner or later if American geography is to keep pace with the world.

Sonora Storms. As explained by Dean Blake (*Monthly Weather Rev.*, Vol. 51, 1923, pp. 585–588), Sonora storms are those that bring the famous cloud-bursts on the west wall of the California desert. These storms were named when it was thought they originated in Sonora, Mex. Now, however, it is known that they develop in California, near where they run their course and end. When Sonoras are in progress their turbulent thunderheads may be seen from the coast, towering majestically above the mountains. The wind aloft flows seaward.

A western position of the desert low pressure area favorable to a large inflow and superheating of moist air from the Gulf of California occurs, on the average, but

one day a year, usually in July or August. On such a day from two to seven, sometimes even more than eleven, inches of rain may fall in one sudden downpour on the valleys and slope over 2000 feet above sea level. Where rain does not reach the ground numerous fires may be set by lightning. The waters roar down the dry gullies and wash away highways, railroads, or any other obstructions in their path. The extraordinarily violent character of these thunderstorm rains is owing to a great abundance of moist air heated to desert temperatures on a generally quiet day. On rare occasions, similar cloud-bursts occur on some western slopes of the Appalachians.

CHARLES F. BROOKS

Per Capita Wealth in the United States. If the value of all property in a given region could be ascertained, and divided by the number of inhabitants, the resulting per capita wealth ought to be one of the best possible measures of standards of living. But there are great difficulties in the way of making accurate estimates of property values. Officials of every state, county, and city receive annual returns of the value of taxable property in their jurisdictions; but some valuable property, such as churches, schools, libraries, city and county buildings, parks and roads, is not taxed at all, some is overlooked, and in many communities property is assessed for taxing purposes far below its real value. (Some of the difficulties were discussed in the third volume of the Compendium of the 11th U. S. Census, 1897, pp. 943–948.)

Estimates of the true wealth of every state (and sometimes of every county) were made by the United States Census Office at each census from 1850 to 1900 (the first three times considering taxable property only) and again in 1904, 1912, and 1922. The results for December 31, 1922, have been published by the Department of Commerce in a series of mimeographed press bulletins of one page each, one for each state, at frequent intervals from December, 1923, to March, 1924; and the whole series was summed up in a four-page printed quarto leaflet issued the latter part of April, 1924, which gives comparative statistics all the way back to 1850.

As measured in dollars the estimated total wealth of the United States increased from about 186 billion in 1912 to 321 billion in 1922, or 72.2 per cent; and the per capita wealth increased from $1950 to $2918, or 49.6 per cent. But the constant fluctuations in the value of the dollar, especially during the World War, must be taken into consideration. Economists agree that average commodity prices in the United States were about 56 per cent higher in December, 1922, than in 1912; so that, instead of being 49.6 per cent richer than we were ten years before, we were really a little poorer. With this in mind we may ask how different states or other communities compare in per capita wealth and in rate of increase thereof. We learn that the estimated per capita wealth in different states at the end of 1922 ranged from $1216 in Mississippi and $1244 in Alabama to $4482 in South Dakota and $6998 in Nevada. It may be noted that in proportion of income tax payers and magazine readers, value of property per farm, and various other matters, the several states had approximately the same rank as in wealth.

But the states with an average per capita wealth below $2000 all have a large proportion of negroes, and if separate figures for different races were available the Southern whites might not rank much below those of the North and West. In 1920 the average white farmer in South Carolina or Florida was about on a par with those in Vermont and New Hampshire. The census does not separate the races in this inquiry, as it does in value of farm property, but the tax assessors of most southern states do.

One method of testing the accuracy of these estimates of wealth is to compare the value of all property per family with that of farm property per farm; for in

most states farm property is more valuable than all other real estate combined, and the average farm is a one-family institution. The number of families and of farms, together with the value of farm property, in any state or county on January 1, 1920, is easily ascertained from the census; and, although the wealth estimates were made three years later, we probably shall not be far wrong if we assume that the increase in real wealth during that period was just about counterbalanced by the decline of prices.

On this assumption the total wealth per family in the United States in 1920 was $13,100, as compared with $12,084 for the value of property per farm. If we eliminate non-taxable, or public, property (in which the farmer of course owns his share), the wealth per family would be about $12,250. This shows that the average farm family in this country is nearly as prosperous as the average city family—which may be contrary to prevailing impressions. On a per capita basis, to be sure, there would be a greater difference, since, as a rule, farm families are larger than city families.

When we consider separate states, however, we find some variations. In Illinois, Iowa, South Dakota, Nebraska, and California the average farm family seems to be about twice as wealthy as the average family (or perhaps three or four times as wealthy as the average city family), while toward the other extreme (omitting a few states that have less than 10 per cent of their population on farms) are Maine, New Hampshire, Pennsylvania, Delaware, West Virginia, Michigan, and several southeastern states, with about twice as much prosperity in the state as a whole as on farms. Statistics of illiteracy and magazine circulation also show a greater difference between city and country in the South than in the North and West.

We may next inquire what states gained or lost wealth during the recent war period. Taking the census figures literally, North Carolina increased 135.2 per cent in per capita wealth between 1912 and 1922, Tennessee 113.6 per cent, and South Dakota 112.9 per cent; while at the other extreme were Oklahoma with 12 per cent increase and North Dakota with 11.6 per cent increase. Those which gained less than 56 per cent and were therefore really poorer were, in descending order, New Jersey, Indiana, Kentucky, Oregon, Washington, Nevada, Alabama, Arkansas, Minnesota, Kansas, Montana, Nebraska, New York, Texas, Illinois, Iowa, Colorado, California, the District of Columbia, Oklahoma, and North Dakota.

So great variations among different states are hard to explain, and one might be inclined to suspect that the estimates are not very accurate. The figures can be checked to some extent by comparing the changes in value of farm property per farm between 1910 and 1920 with the changes in estimated per capita wealth between 1912 and 1922; for it does not seem likely that total wealth could increase much while farm property declined in value, or vice versa, except in densely populated states where farming is relatively insignificant.

The states which increased both in value of property per farm and in per capita wealth during the war and the years immediately before and after it (making allowance for the decline in purchasing power of the dollar), were South Dakota, Florida, Tennessee, and North Carolina; and they must therefore be regarded as having rather enterprising (or at least fortunate) inhabitants. Arizona, New Mexico, South Carolina, Georgia, Utah, and Virginia increased perceptibly in one particular but did not change much in the other; Missouri, Ohio, Kentucky, and Louisiana kept about the same rank in both; Illinois, Kansas, Texas, Oklahoma, and Alabama held their own in one and declined in the other; while Nevada, the District of Columbia, California, North Dakota, Washington, Montana, and New York declined in both respects and therefore presumably lowered their standards of living. The remaining 22 states gave contradictory results, gaining in one respect and losing in the other.

Whether the changes in standards of living that have been indicated above are due mainly to the migration or dying off of superior or inferior individuals or to changes in the prosperity of the same individuals or in the size of families cannot be told from the data available but deserve careful investigation in the states that have shown the greatest changes. The agricultural census of the United States that is planned for 1925 should throw considerable light on the subject, at any rate in the southern and western states.

ROLAND M. HARPER

Some Recent Geographical Bibliographies with Special Reference to North America. American students undertaking mature studies in the regional geography of their own continent cannot afford to neglect two European bibliographies that cover the subject. In the periodically issued volumes of the French *Bibliographie Géographique* and of the German *Geographisches Jahrbuch* will be found the only critical lists in existence of recent publications on the regional geography of North America.

The *Bibliographie Géographique* was reviewed in the *Geographical Review* for 1923 (Vol. 13, p. 480), and a plan for the co-operation of the American Geographical Society in its future publication was announced in the July, 1924, number of the *Review*, page 469. The *Geographisches Jahrbuch* first appeared in 1866 and has been continuously edited since 1880 by the veteran professor, Hermann Wagner, of the University of Göttingen. Each volume contains a series of summaries of the progress of recent investigation in various departments of geography with abundant footnote references to books, articles, and maps. Summaries dealing with the same topic are not repeated in every successive volume but only after intervals the duration of which depends largely upon the relative importance of the topic itself.

The current number of the *Geographisches Jahrbuch*, Vol. 39, 1919–23, was published in the spring of this year (1924). The dates "1919–23" on the title page are misleading, for the actual contents of the volume deal in large part with publications of an earlier date than 1919. Summaries are given of the progress of recent investigation in the following fields (figures in parentheses indicate the number of footnotes and hence, essentially, the number of publications referred to): historical geography of the Roman West, 1910–1914 (509); geographical meteorology, 1912–1916 (1560); the geomorphology of the earth's crust (*Dynamik der festen Erdrinde*), 1913–1921 (858); geophysics (129); regional geography of Africa, 1913–1922 (991); and regional geography of North America north of Mexico, 1914–1921 (1076).

We wish to call particular attention to the last-named summary. Professor Kurt Hassert of Dresden here continues and brings nearly to date a series of similar reviews contributed by Professor Emil Deckert to the *Jahrbuch* for 1914 and preceding years (for references see J. K. Wright: Aids to Geographical Research, *Amer. Geogr. Soc. Research Series No. 10*, New York, 1923, p. 42, footnote 5, No. 30). Professor Hassert introduces his study with apologies for omissions and points out the handicaps under which he labored in obtaining American publications as a result of the war and of post-war conditions in Germany. These apologies, we feel, are hardly necessary. The compiler seems to have "caught" not only everything that is obviously essential but also a large quantity of important and interesting items buried in government documents and in obscure periodicals and society proceedings. It is a revelation to scan his list and to observe the wide range of distinctively geographical writings that is being produced by various agencies in this country. The material is admirably organized and presented in systematic order. No less than 73 references are given to publications on the "continent as a whole," including a suggestive group on the Norse voyages. Some 76 references are to publications on Alaska. To British North America there are devoted at least 418, and

to the United States as many as 708. The material on the United States includes discussions of contributions to the study of natural regions, geology, climate, plant geography, problems of population and race (10 references on the negro question), economic geography, history of geography and exploration, followed by subsections devoted to the various regions of the country, with some 361 references to regional studies.

Two other recent works relating exclusively to North America also deserve mention. First there is the United States Bureau of Efficiency's "Report on the Statistical Work of the United States Government Submitted to Congress in Pursuance of the Acts of March 1, 1919 and November 4, 1919," Government Printing Office, Washington, 1923. This volume is a statement regarding the statistical activity and publications of the various bureaus, offices, commissions, and services of the government. The second publication is John M. Nickles' "Geologic Literature on North America, 1785–1918," Part I, Bibliography (forming *U. S. Geol. Survey Bull. 746*); Part II, Index (forming *U. S. Geol. Survey Bull. 747*), Government Printing Office, Washington, 1923. This, as is explained in the introduction, is in the main a cumulation of the series of bibliographies of North American geology that have hitherto been issued as *Bulletins* of the U. S. Geological Survey, "though many titles not found in these bulletins have been added as a result of the examination of the bibliographies on particular subjects issued by the Survey and many other special bibliographies and from other sources." Nickles' volumes will be indispensable for the geographer in search of material on the physiography or mineral resources of the continent.

Finally, reference should be made to a work of more general scope: Edward B. Mathews' "Catalogue of Published Bibliographies in Geology, 1896–1920" (*Bull. Natl. Research Council*, No. 36, Vol. 6, Part V, October, 1923). This is a simplified continuation of Emmanuel de Margerie's famous "Catalogue des Bibliographies Géologiques." Paris, 1895, and forms a list of bibliographies dealing with all branches of geology in all parts of the world. Arranged by topics and supplied with an authors' index, it incidentally includes references to bibliographies of the highest geographical value.

EUROPE

The View from Mont Blanc: Switzerland As Seen from the Air. A clear view of the entire horizon from a high mountain in our stormy latitudes is rarely to be had even by the mountaineer. M. Paul Helbronner by means of a remarkable panorama has made it possible for the sedentary reader to study the details of the immense prospect from Mont Blanc and to enjoy its marvelous colors. Painted in 1899–1900 from photographs taken in 1891 and 1893, the panorama has recently been published in photogravure reproduction (Paul Helbronner: Description géométrique détaillée des Alpes françaises, Annexe du Tome Second, Les origines iconographiques de l'oeuvre géodesique, Paris, 1921, Feuilles I à XIII. On the geodetic work of Helbronner as a whole see *La Géographie*, Vol. 37, 1922, pp. 117–131). The thirteen sheets of the panorama pasted together form a strip 19 feet 8 inches long by 25 inches wide. A key in black and white 4½ inches wide is given beneath the colored strip (upon which no names are written) making it possible to identify the details of the view.

The portfolio containing the panorama also includes views of the summit of Mont Blanc and its surrounding peaks from lesser eminences in the immediate vicinity. These show the light effects at different times of day. Especially impressive is a view of Mont Blanc from the Col de Géant at five o'clock in the morning in August. The rising sun tints the higher snows and rocks with delicate shades

of rose and orange while the lower crags are dark purples and violets, and the glacial ice a cold blue.

Though no photographs can vie with Helbronner's water colors in beauty, as an aid to geography-teaching Dr. Otto Flückiger's album of 243 airplane photographs of Switzerland will probably be even more valuable (Die Schweiz aus der Vogelschau, edited with introduction by Dr. Otto Flückiger, Zürich, Munich, and Leipzig, 1924). The geographical significance of the airplane photograph has often been commented upon (see, for instance, W. T. Lee: The Face of the Earth As Seen from the Air, *Amer. Geogr. Soc. Special Publication No. 4*, New York, 1922), but Dr. Flückiger's volume is probably the first in which a large number of airplane photographs have been systematically assembled and published to illustrate the geography of a fairly large area. In the introduction the editor discusses the physiographic and anthropogeographic features of three main regions of Switzerland: Alps, "Mittelland," and Jura. A further brief explanation interprets the specific and typical points of geographical interest revealed by the several photographs. So widely distributed and carefully selected are the views that almost no element in the visible geography of the country is unrepresented among them: complex and folded mountains, U- and V-shaped valleys, *névés*, glaciers, lakes, rivers, flood plains, deltas—all are displayed in a variety of forms in each case. Views of rural districts, with their diverse patterns of field and woodland supply an abundance of material for the human geographer. Students of city geography more particularly will profit from studying the views of towns, some taken at sufficiently low levels to show house forms, roof construction, and the intimate tracery of streets. The contrasting aspects of the country at different seasons are revealed, and, though most of the pictures were taken in clear weather, a few present characteristic views of clouds, haze, and mists nestling in the valleys.

In Helbronner's panorama we may look westward across the Rhone valley, over the site of Lyons (the city itself is masked by nearer hills), to the remote sky line of the Massif Central. Eastward the eye sweeps out to the plains of Piedmont and the northern Apennines. In Dr. Flückiger's volume large portions of Switzerland are often spread out below us in a single plate; one photograph embraces virtually the entire Lake of Lucerne with a vast expanse of intervening country. Mountain panoramas and airplane photographs give us an impression not only of the detailed forms and appearances of the various features which they depict but also a visual conception of areas which nothing else, short of actually seeing the country itself, can give. The importance of training in the visualization of areas is something that ought not to be overlooked in geographical education.

Ancient Types of Rural Dwellings in France. A generation ago Meitzen wrote his great tomes on settlement and agriculture, and a famous section of his work dealt with old types of houses. He ascribed the agglomerated village with its cornfields apportioned in strips in France to the Germanic invaders of post-Roman times, and with this came the idea that the Gallic house was a modification of the German house. It is said to have a steep roof, usually of thatch, façade under the edge of the roof, rectangular shape with the shorter side of the rectangle under the gable, a yard, one room for human beings and one for animals at first, and a barn above under the roof. Albert Dauzat in a recent paper in *La Nature* (January 26, 1924), however, shows that when one goes up into the Pyrenees from the plain of the Garonne and when one goes up into the Alps from the Rhone near Lyons one goes from the Mediterranean, or later, type of house, with fairly flat roof and other features detailed by the author, to this Gallic type. In other words he infers a spread of a later type in the plains both up the Rhone to about Tournus, with an important island beyond, and down the Garonne and northward in a coastal

zone to the Loire; and he concludes that this limited the distribution of an older type which he calls Gallic and supposes to date back to Roman times or beyond. His Norman type of house has its distribution interestingly correlated with that of several types of place names and with features of land tenure; it is often built with timber beams in the façade. Among his other types are the Flemish or Rhenish (Germanic), the Alpine, the Jurassic, the Basque, and others. A very interesting map accompanies the article, obviously a sketch to be amplified by further work; many striking departures from what might be considered geographic controls are noted. Lack of coincidence between boundaries of house types and boundaries of dialect is explained on the basis that the first conforms to relations chiefly from the first to the fifth century A. D., while the second became fixed from the seventh to the eleventh. More modern changes are noted here and there.

H. J. FLEURE

The Geographical Position of Budapest. In the International Edition of *Földrajzi Közlemények: Bulletin of the Hungarian Geographical Society* (Vol. 41–46, 1913–19, Budapest, 1923, pp. 1–29) there is an article in English by Dr. Eugen de Cholnoky entitled "The Geographical Position of Budapest," a welcome contribution to a growing literature on city geography (see M. Aurousseau: Recent Contributions to Urban Geography: A Review, *Geogr. Rev.*, Vol. 14, 1924, pp. 444–455).

Dr. Cholnoky divides the Hungarian basin into six main productive regions. Separating these he conceives of *market lines* along which market places and market towns have sprung into existence where an exchange of the products of the different regions takes place. Among these lines the most important is one which runs from the vicinity of Agram (Zagreb) northeastward to Sátoraljaujhely along the southeastern foot of the highland zone separating the two plains of Hungary, the Greater from the Lesser Alföld. A normal position for a great city is at or near the point where the Danube cuts through the highland zone and across this market line. This passage of the Danube, centrally located in relation to the entire Hungarian basin, is, in the words of Dr. Cholnoky, "a remarkable spot full of geographical energy." It was essentially this circumstance that determined the growth of Budapest after the frontier of settlement had finally swept eastward into the Greater Alföld.

A combination of local topographic circumstances has favored the development of the town in its immediate site: the presence of a suitable river crossing here and here alone in a stretch of many miles up and down stream; easy land communication with the Little Alföld by way of the transverse valley of Vörösvár through the uplands to the northwest; a strong citadel in the fortress hill of Buda; an abundance of local building material.

Space forbids our following Dr. Cholnoky's illuminating discussion of the interior geography of Budapest, of the relations of the city to fluvial terraces, or of the floods to which the built-up section has occasionally been subjected where, in part, it occupies an abandoned channel of the Danube. The article is illustrated by a block diagram of the "morphology of the surroundings of Budapest." The author, though he has succeeded admirably in representing the surface features upon this diagram, has made no attempt to indicate the subterranean structure.

Distribution of Population in Norway. Sten De Geer's admirable map of distribution of people in Sweden (1917) has been extended to Norway by one of his pupils, Alfred Söderlund, with the same method of representing each 100 people by a black dot one millimeter in diameter, and towns of more than 3000 people by spheres whose volume represents the number of their inhabitants on the same scale. The result is a vivid presentation of the way the people of Norway cling to the coasts and the southeastern valleys, both city folk in 75 towns and cities and the

dwellers in the country (see Fig. 2, p. 507, a reproduction on a reduced scale of two portions of the map).

Norwegian authorities (Norges Geografiske Opmåling og det Statistiske Centralbyrå) who publish the work—"Folketetthetskart over Norge," Christiania, 1922, and text, "Befolkningens Fordelingen i Norge," Christiania, 1923—adopted a scale of 1:1,000,000, half that of De Geer's map for Sweden. Probably on that account Söderlund has omitted many of the physiographic and forestry data included on De Geer's map, limiting himself to black dots for population, red lines of communication, blue for hydrography and boundaries on a flat yellow tint, with an abundant selection of place names in light brown—all very clear. The smaller scale has of course the advantage of getting all Norway into the space of two sheets, which makes for ease of inspection. The distribution here shown was remarkably foretold by the impressionistic map in 1:3,600,000 published by the government in the work "Norway," prepared in 1900 for the Paris exposition; but Söderlund's work adds detail and expression, besides including the cities, which of course belong if the city folks are really folks. It is a picture of an inhospitable land, to every soil-covered spot of which men cling in swarms, everywhere close to great expanses of desert wastes. The cultivable earth is scarce. Only about Christiania Fiord and Lake Mjösen in the southeast are continuous patches of as much as a hundred square miles of tillable soil to be found. There live half the people of the country. People swarm too in the great eastern valleys that lead out from the Christiania region to the north and west—Östendal, Gudbrandsdal, Valdres, Hallingdal, and Numesdal. In Gudbrandsdal, especially, no mile is without human habitations, though Norway is one of the most sparsely peopled countries in the world. For this narrow strip of culture lies between twenty-mile-wide expanses of desert fell to right and left. The empty fell comes close to Christiania itself on the east and north, widening out notably in the western interior into the great wastes of the Hardanger Vidda, Jotunheim and Dovrefjell. But the coast settlements show most surprising continuity. Along the 1700-mile coast (in detail it develops into a 12,000-mile coast) it is only in the remotest north that one can find a ten-mile stretch without inhabitants. East of Christiansand (latitude 58° N.) there are 650 people to each linear mile of coast, north of Trondhjem there are 170, near Bodö 220, and at Hammerfest 120. The coast zone in which these people are included is 20 to 40 miles wide, the whole labyrinth of fiord, valley, and island passages making up the Norwegian coast. Except in the Christiania region the Norse people live close to the sea but almost invariably at the edge of an empty upland whose desert surface overhangs the salt water of the Atlantic.

MARK JEFFERSON

On the Late Quaternary History of the Baltic: A Reply. In an article "On the Late-Quaternary History of the Baltic" (*Geol. Fören. Förhandl.*, Vol. 46, 1924, pp. 172–179, Stockholm) Henrik Munthe gives his latest views of the late-Pleistocene changes of level of the Baltic especially as far as they disagree with views expressed by the undersigned ("On the Late-glacial and Post-glacial History of the Baltic," *Geogr. Rev.*, Vol. 12, 1922, pp. 602–612).

The highest limit of the Baltic ice lake before its drainage at the northern end of Mt. Billingen is put 40 to 55 meters higher than previously, and the highest marine limit on the western side of southern Billingen about 20 meters higher. The amount of the drainage of the Baltic ice lake at the northern end of Billingen is thus believed to have been about 56 meters. This view, however, is only one of five. G. Lundqvist ("Den baltiska issjöns tappning," *Geol. Fören. Förhandl.*, Vol. 43, 1921, pp. 381–385) thinks that the lowering was from 149 meters to 132 meters; S. Johansson ("Baltiska issjöns tappning," *Geol. Fören. Förhandl.*, Vol. 45, 1923, pp. 392–396),

without giving any elevations of beaches, thinks that the lowering exceeded 35 meters; M. Sauramo ("Studies on the Quaternary Varve Sediments in Southern Finland," *Bull. Comm. Géol. Finlande*, No. 60, 1923, pp. 125–128) believes that no drainage worth mentioning took place; and W. Ramsay ("On Relations Between Crustal Movements and Variations of Sea Level During the Late-Quaternary Time Especially in Fennoscandia," *Bull. Comm. Géol. Finlande*, No. 66, 1924, p. 27) thinks that the sinking was from 149 meters to between 112 and 120 meters. It is important to notice that Lundqvist and Ramsay agree regarding the elevations of the beaches although they disagree about their relative age. The beaches to which they attach importance also have been studied by other geologists. Therefore Munthe's new figures appear to be doubtful or to belong to small lakes ponded between the south-Swedish highland and the receding ice sheet. Whether Lundqvist's or Ramsay's view is the correct one is difficult to judge at present. The drainage of the Baltic ice lake at the northern end of Billingen consequently may have amounted to 17 meters (Lundqvist) or between 29 and 37 meters, say 33 meters (Ramsay). The threshold between Falster and the German mainland, the Darsser Schwelle, now reaching to within 18 meters of the surface, at that time must have stood at least (18 + 17) 35 meters or (18 + 33) 51 meters higher than now.

The depressions in the Öresund, the Belts, and the Cadet Rinne in the Darsser Schwelle are by Munthe still believed to be old river channels. Fortunately there is an excellent bathymetrical map of the region (Hans Spethmann; Tiefenkarte der Beltsee, *Petermanns Mitt.*, Vol. 57, II, 1911, pp. 246–251, Pl. 29). This map shows that the oblong depressions are separated by thresholds that are very high and wide. In the Little Belt, with the exception of a small kettle-shaped hole 81 meters deep, deep parts are lacking; wide sills rise even to between 20 and 10 meters from the water surface. But the deep hole of 81 meters in Munthe's mind nevertheless indicates the base of river erosion in Ancylus time. The depressions, as Gerard De Geer pointed out, most probably mark lines of fracture. Their present shape may be due partly to the activity of the land ice.

Of the facts set forth by Munthe as proof that the Baltic during the Ancylus stage was a lake and not an inland sea, only one is new. It is also, after more than 35 years, the first one of value; while the old facts can be readily explained under the assumption that the Baltic of that time was an inland sea. The new fact is the existence of an outlet channel in central Sweden of the Baltic during Ancylus time. The threshold lies about 15 meters above the contemporaneous sea, while the level of the Baltic stood 20 meters above the then sea.

ERNST ANTEVS

Ice Sheets and Isostasy: Relations in Fenno-Scandia. The relationship between the North European ice sheet and the late-glacial and post-glacial changes of level of Fenno-Scandia are discussed in a recent paper by Albrecht Penck ("Glaziale Krustenbewegungen," *Sitzungsber. Preuss. Akad. der Wiss.*, Vol. 24, 1922, pp. 305–314). He starts from T. F. Jamieson's theory—accepted by Gerard De Geer in 1890—that the post-glacial elevation of the glaciated regions was due to the disappearance of the ice which had locally weighed down the earth's surface and pressed out the underlying magma to the regions lying outside the glaciated area.

From the estimated volume of the last ice sheet, whose average thickness is assumed to have been 1000 meters, the amount of the magmatic displacement is calculated. The volume of the magma returned, figured from Henrik Munthe's isobases, is found to be only one-fourth of the quantity probably pressed out. The great difference is due to various causes. In the first place the elevation is greater than the isobases suggest because of the rise of sea level as the water imprisoned in the ice sheets was restored to the sea. This rising may have amounted to about

40 meters. In the second place upheaval occurred while the land was still covered by ice. Assuming a uniform rise, 7000 years is found to be the length of post-glacial time (it should be 8500) and 5000 years as the time of ice retreat from across Sweden. Using Munthe's isobases the author finds that the probable average upheaval of Fenno-Scandia, taking into consideration the rise of sea level, amounts to 212 meters. In the third place the true zero isobase lay far outside the apparent one. The area of upheaval practically coincided with the area of glaciation.

Even so, there is a great difference in the amount of magma pressed out and returned. This difference, however, is natural. Magma is still flowing towards the now rising area of Fenno-Scandia.

Theoretically it is probable that the rising, from being zero at the beginning of the ice retreat, increased and reached a maximum after the disappearance of the ice in order to decrease gradually to zero. This hypothesis seems to be supported by A. G. Högbom's survey of the oscillations of level. Under the assumption that the rhythm expressed by Högbom's curves of the oscillations for central and northern Sweden occurred in the whole of Fenno-Scandia, it is argued that the rate of upheaval increased from practically zero during the 15th millennium before the Christian era to a marked maximum during the 8th millennium after which it fell to an unimportant minimum during the 5th millennium, rose, and slowly decreased down to the present. Much the same problems are discussed by Fridtjof Nansen in "The Strandflat and Isostasy" (see below).

However interesting Penck's calculations are, they must not be taken too literally, since to a large degree they are based upon more or less unknown conditions. In the first place, it does not seem likely to the undersigned that magma corresponding to the weight of the ice ever was pressed out from the glaciated area. The ice probably began to retire before equilibrium was reached, judging from the fact that stability is not yet reached in the Baltic region so many thousand years after the disappearance of the load. Therefore the amount of outpressed magma calculated from the volume of the ice sheet may be too large. In the second place the figure 212 meters as the average amount of elevation is quite arbitrary. In reality it represents the average upheaval under the given conditions during the last 12,000 years. Rising probably occurred before that time. Therefore, and because the upheaval has been very irregular, we are not yet in a position to estimate the actual rise. The position of the zero isobase at the time of the greatest depression is not known. But at the uncovering northern Germany stood above the sea level of that time and actually at least as high as at present, provided that the sea level did not stand more than some 40 to 50 meters below that of the present time.

The rhythm of the oscillations of level in Sweden may not have been that assumed by Penck, who follows Högbom's survey. The subject is being studied by essentially new methods by Gerard De Geer, G. Lundqvist, and others; and our view of it is likely again to undergo fundamental changes. The present rise of Fenno-Scandia is only partly a direct continuation of the post-glacial rise. So, for instance, Bohuslän, which is now rising at a rate of 4 millimeters a year (10 meters in 2500 years), takes practically the same level as it did 2500 years ago.

ERNST ANTEVS

The Strandflat and Isostasy: A Further Comment. Fridtjof Nansen's important work "The Strandflat and Isostasy" (1922) was briefly reviewed by Professor W. M. Davis in the *Geographical Review*, Vol. 13, 1923, pp. 646–647. The present writer would here enlarge upon one of the aspects of the work—the problem of isostasy and late-Pleistocene changes of level in the Fenno-Scandian area (compare the preceding note).

The Norwegian strandflat may have been formed by the joint action of subaerial erosion by frost, local glaciers, etc., and of marine shore denudation by frost and wave action since the coast had been dissected by numerous fiords and channels and especially before, during, and after each glacial period. On the whole, the levels of the strandflat appear now to stand at similar inconsiderable heights above the sea in all parts of the Norwegian coast where they have been studied. A computation of existing data on the late-glacial and post-glacial upheaval of the Norwegian coast regions from Christiania to the Kola Peninsula tends to show that this upheaval has proceeded with remarkable regularity and uniformity. These facts constitute conclusive evidence that the earth's crust in these regions has very nearly returned to the same horizontal position it had before the last glacial submergence, except that the shore line then stood perhaps between 10 and 17 meters higher, in relation to the land, than it does now. "The uniform relation which we have found between the heights of the observed upper limit of late-glacial submergence and those of the Tapes line confirms in a striking manner the correctness of these conclusions" (p. 273). The upheaval of the land along the whole Norwegian coast may have practically ended. The Tapes-Littorina submergence—the only interruption of the upheaval which Nansen discusses—cannot be explained as an isostatic phenomenon but may be due to transgression because of rapid rise of the sea level while Fenno-Scandia except South Sweden was slowly rising. The rise of the sea may have been due to the melting of ice caps and glaciers because of the high temperature at that time. The subsequent drop in temperature may have caused an increase of the ice caps and sinking of the sea-level. The different stages or interruptions in the upheaval of the land, marked by a series of marine terraces and raised beaches along the coast of Norway, may be similarly explained.

Thus, the strandflat probably since pre-glacial time has represented the level of isostasy at times when the land was not depressed by a load of ice; for otherwise it seems to be inconceivable that the crust should always return to the same horizontal level after each depression. Thus, it may be inferred "that the earth's crust is on the whole very responsive to disturbances of its equilibrium and has a great ability to re-establish it. After a sufficient time it will attain its level of isostasy at least within some few meters" (p. 296).

The vertical coastal movements in Fenno-Scandia are explained in the old well-known way essentially by outpressing and subsequent return of magma caused by the loading and the subsequent unloading of the ice.

Calculating on the basis of an extension of all the Pleistocene ice sheets during their maximum development of 50 million square kilometers and an average thickness of the ice sheet of 1000 meters, Nansen finds that the sinking of the general sea level during the climax of glaciation may have amounted to 100 meters at least and perhaps to as much as 150 meters. The value of Nansen's conclusions depends largely upon whether or not his explanation of the formation of the strandflat is correct. If it is correct the ancillary results are remarkable indeed and very far-reaching. However, the great uniformity of the changes of level which Nansen's view postulates appears to be a weak point. Regarding late-glacial and post-glacial oscillations of level other students of the subject find less uniformity. For instance, J. Rekstad's map of the late-glacial submergence ("Norges hevning efter istiden," *Norges Geol. Undersökelse No. 96*, Christiania, 1922) shows a more irregular course of the isobases than does Nansen's map (Fig. 166, p. 255). The reason is that Nansen has sifted the material (see, for instance, pp. 248, 254, 262, and 272).

When Nansen ascribes the Tapes-Littorina transgression largely to ice melting, he overlooks the known fact that the warmth maximum fell substantially later in time than the transgression. Terraces and shore lines formed during the upheaval were more likely due to land upheaval by jerks than to rise of the sea level. Because of the rigidity of the earth's crust upheaval may have begun when equilibrium was

surpassed, and through inertia it may have proceeded rapidly so as to surpass the state of equilibrium in the other direction. If the upheaval had proceeded only a little too far, the level was kept, especially as the ice load was continually decreasing; but if it proceeded far beyond the point of equilibrium a movement in the opposite direction and a sinking of the land resulted. This may have been the essential cause of the oscillations of land in Fenno-Scandia during the general upheaval.

ERNST ANTEVS

The Economic and Political Status of Russia in 1923. Information drawn in large part from the Russian periodical press and relating to the economic and political situation of Russia in 1923 is summarized in a note by P. Deffontaines in *La Géographie* for February, 1924 (Vol. 41, pp. 187–196).

From the agricultural point of view, Russia in 1923 had once more become a country of export after the famine years of 1920 and 1921. An effort was being made by the Soviet authorities to encourage improvements in agricultural methods through the introduction of model farms and to bring about a more productive utilization of field and forest by establishing new agricultural communities and by granting concessions to foreigners on a large scale. Vast tracts of forest in the basins of the northern Dvina and Vichegda have been conceded to Anglo-Russian and Dutch-Russian concerns.

A commercial and industrial crisis occurred in 1923, the result of "the lack of financial means, leading to great difficulties in selling and buying merchandise, and of the cessation of all active operation on the part of the banks." Selling below cost and overproduction were general in many industries, and as a consequence many establishments had to close down. Figures for the foreign trade of Russia for 1922 as compared with those for 1913 show that imports from Germany had fallen from 57.5 per cent to 33 per cent of the total imports, though the latter percentage was double that of 1921. Imports from the United States showed an increase from 8 per cent in 1913 to 14 per cent in 1922; those from England in the same years of from 12 per cent to 18 per cent. Thirty per cent of the 1922 exports of Russia found their way to England; exports to Germany in that year were negligible, though the situation was materially altered in 1923 by the resumption of the exporting of Russian cereals.

Monsieur Deffontaines states that "the fact which dominates the entire political situation of present-day Russia is the disintegration of the Russian nation." By granting autonomy to the ethnic stocks of the former empire and by encouraging the use of local languages "the Soviets have to some extent organized and stimulated this disintegration." Other authorities see a trend in the opposite direction. W. Gerbing, in an article entitled "Das neue Russland" (*Geogr. Zeitschr.*, Vol. 29, 1923, pp. 197–205), asserts that "in the contemporary administrative division of Russia we may perceive the attempt to found anew and to strengthen the dominance of Great Russia, while at the same time the newly awakened national feeling of the numerous non-Russian peoples is indulged." Monsieur Deffontaines considers the recent change in the name of the body politic as a whole from "Russian Federated Socialist Soviet Republic" to "Union of the Socialist Soviet Republics" as if it were a further concession toward a policy of decentralization. Gerbing, on the other hand, regards it as symbolizing a change from a loose federation of half-sovereign states into a genuine union, or, as he puts it, from a *Staatenbund* to a *Bundesstaat*, and this view is confirmed in the recent well-documented volume of A. L. P. Dennis, "The Foreign Policies of Soviet Russia" (New York, 1924), pp. 189–196, as well as in Captain Kelly's article in the present number of the Review.

AFRICA

The Practice of Transhumance in Basutoland. Basutoland falls into two major natural regions: the lowland sandstone country of the west, the Basutoland of the natives, and the volcanic upland country—the Malutis of the natives. The upland is a maturely dissected plateau with elevation ranging from about 6500 to 11,170 feet in the culminating peak of the Drakensberg and is limited by eastern and western escarpments, the Drakensberg and Malutis. The rock weathers to a fertile black soil which grows excellent crops of wheat. But the Basuto greatly prefers maize or Kafir corn as a staple, and the population of the country is still concentrated in the warm lowlands. The long steep grassy slopes of the uplands are used as pasture for the Basuto's wealth of cattle, sheep, and goats. Associated with the cattle industry is the practice of transhumance (R. U. Sayce: An Ethno-geographical Essay on Basutoland, *Geogr. Teacher*, No. 68, Vol. 12, 1924, Spring, pp. 266–288, London).

In autumn the cattle come down from the mountains. The precise date is set by the time of harvest, for they are grazed on the stalks of the garnered maize and corn; and, when this fodder is exhausted, on the winter veld, pasture near the village demarcated and set aside in the spring for this purpose. In Basutoland there is no private ownership of land; agricultural allotments are made each spring by the chief, who also declares the grain fields and the winter veld open for common grazing towards the end of May or the beginning of June. The winter pasture available is limited, and the cattle are usually in poor condition by the end of the winter when the great spring movement takes place. About August early rains—Basutoland is a region of summer rain—have revivified the mountain pastures, and the homelands are waiting to be plowed. A few cattle are kept behind for milk and plowing, the rest go to the mountains under the charge of herdboys "old enough to know the cattle marks." Little ceremony attends the proceeding. Distances traveled vary: it may be a matter of a few hours or a day or several days' journey. Some exchange of beasts goes on all summer, and in certain particularly rich agricultural districts where considerable numbers of cattle are kept at the villages there may be a large secondary migration towards the end of December and January. Where the mountain posts are large, cattle, sheep, and goats are looked after separately; but usually two boys care jointly for flocks and herds. When the cattle come down, the sheep and goats usually remain behind under the care of a single boy.

The pressure of increasing population is, however, making itself felt in Basutoland. Formerly a man could have as much agricultural land as he could cultivate; now he is limited to three plots, each 100 by 150 yards. The population is spreading into the mountains; permanent villages and cultivation are taking the place of the cattle posts; and a taste for wheat and extension of the crop is being perforce developed. Associated is a growth of individualism and private ownership. Migration movements are being correspondingly restricted. As in other lands of more advanced civilization, transhumance is on the wane in Basutoland (Philippe Arbos: The Geography of Pastoral Life, Illustrated with European Examples, *Geogr. Rev.*, Vol. 13, pp. 559–575). A change in the character of the pastoral industry or its decline is connoted; as it is, the pastures are overstocked, and the range has deteriorated as elsewhere in South Africa.

ASIA

Some Recent Maps of Central Asia. During his expeditions in Central Asia (1900–1901, 1906–1908, and 1913–1916) Sir Aurel Stein enjoyed the full co-operation of the Survey of India. As a result, in addition to making the archeological discoveries that have amazed the scholarly world, he was able to carry out carto-

graphical work of primary importance. The definitive cartographical results of the three journeys have been embodied in a series of 47 maps (1: 500,000) accompanied by a volume entitled "Memoir on Maps of Chinese Turkistan and Kansu from the Surveys Made During Sir Aurel Stein's Explorations, 1900–1, 1906–8, 1913–5" (Records of the Survey of India, Vol. 17, Trigonometrical Survey Office, Dehra Dun, 1923). These maps supersede the 94 maps (1: 253,440) based upon the expedition of 1906–1908 and published as the fifth volume of "Serindia" (see *Geogr. Rev.*, Vol. 12, 1922, p. 662).

Stein explains in the introductory note to the "Memoir" that "improved methods of drawing and reproduction have allowed in the new maps a clearer and fuller representation of [the record of his surveys] than was possible in previous publications." The scale of the new maps is smaller than that of the 1: 253,440 sheets. On the other hand, the new maps reveal all the details that are shown upon the older, as well as various corrections made in the light of more recent data. The representation of relief by form lines (or rough contours) rather than by hachures is more precise. Furthermore, the 1: 500,000 series shows the results of all three expeditions whereas the 1: 253,440 series shows those of but one expedition only.

The detailed topography of the new maps has been exclusively derived from the plane-table surveys carried out by Stein's parties. These plane-table surveys were based upon the triangulation and astronomically determined latitudes of the Indian surveyors, Rām Singh and Lāl Singh, under Stein's orders. The triangulation in turn was to a very large extent based upon Captain H. H. P. Deasy's triangulation in the Pamirs and Kunlun (1897–1899), though the work of a few other explorers was also drawn upon for latitudes and longitudes. Major Mason, commenting on the triangulation in an appendix to the "Memoir," highly commends its accuracy; he adds, however, that "it is absolutely necessary to lay stress on the fact that it is in the nature of pioneer work and that when the regularly connected triangulation of the Survey of India reaches the areas concerned, the points of Rām Singh and Lāl Singh will be superseded. . . ."

The "Memoir" gives a brief history of Stein's expeditions, a general description of the regions surveyed, a discussion of the compilation and content of the maps themselves with notes on the individual sheets, and an index of local names. Appendixes by Major Kenneth Mason and Dr. J. De Graaff Hunter, both of the Survey of India, treat respectively of triangulation and altitude observations. The volume concludes with a series of photographs.

The general description is an outline of the essential features both of the physical and the human geography of this immense but little-known part of Asia. Though the entire tract has been described at length in Stein's earlier works (to which detailed references are given in the footnotes) all students will appreciate having the material presented in condensed and concise form. The descriptions of the individual sheets not only explain the technicalities of the survey work from which each sheet was constructed but also give brief accounts of the more striking points illustrated by each, again with references to Stein's earlier works. Great care was given to the accurate recording and transliteration of local names as shown on the maps and listed alphabetically in the index. The "Memoir," in short, should serve as a guide of exceptional utility for all who would undertake studies, either general or detailed, in the geography of Central Asia.

Another important recent map of Central Asia is Colonel A. H. Byström's "General Map of Eastern Turkestan and Tibet on the scale of 1: 1,000,000, embracing Dr. Sven Hedin's routes 1894–1908 and those of other recent travelers as well as the most important materials existing," Lithographic Institute of the General Staff of the Swedish Army, Stockholm (undated). This is included in the map supplement to Sven Hedin's "Southern Tibet," 9 vols., Stockholm, 1916–1922. As the title implies, it is a compilation from various sources and consequently may be

used to fill in many of the gaps left by Stein's maps. As Byström's map appeared before Stein's 1: 500,000 series, it does not show the results of Stein's explorations of 1913–1916 nor the various corrections of the latter's earlier maps. Colonel Byström's production is highly artistic and is beautifully engraved. Relief, however, represented by brown shading, is less precise than upon the maps of Stein.

AUSTRALASIA AND OCEANIA

Exploration in Papua. A half century ago the interior of Papua (the official name of southeastern New Guinea) was absolutely unexplored, and even the coasts were imperfectly known. So complete was European ignorance of this region in 1875 that a certain Captain (?) Lawson had the audacity to publish a book describing a wholly fictitious expedition across the island from south to north in the course of which a vast lake and a mountain 32,783 feet high were encountered (J. A. Lawson: Wanderings in the Interior of New Guinea, London, 1875. Lawson's statements, which won some recognition, were refuted by Captain John Moresby in his "Discoveries and Surveys in New Guinea and the D'Entrecasteaux Islands," London, 1876, pp. 321–327). Even as late as 1912 Judge J. H. P. Murray, lieutenant governor of Papua, opened the chapters on the history of Papuan exploration in his authoritative volume, "Papua, or British New Guinea" (reviewed in *Geogr. Rev.*, Vol. 1, 1916, p. 163), with these words: "Papua has been British for nearly thirty years, but half of it is still totally unexplored, and of the other half there is but a comparatively small portion that is really well known" (p. 247). Light had been thrown on much of the eastern half of the territory by the important journeys of Sir William MacGregor in the nineties, and by the reports of government officials, prospectors, and miners. The western half, except for the courses of the main rivers—and of only a few of these—was still *terra incognita*.

The last decade, however, has seen the steady progress of exploration "by magistrates and others as part of their ordinary duty," with such significant results that Judge Murray is able to assert in a recent pamphlet (J. H. P. Murray: Recent Exploration in Papua, Sydney, n. d. [1922 or later]) that "there is really very little left to explore now in Papua, beyond a block east of the Strickland and north and northeast of the Samberigi Valley. Practically all the country west of the Fly has been examined, including the extreme N. W. corner [see Leo Austen: The Tedi River District of Papua, *Geogr. Journ.*, Vol. 62, 1923, pp. 335–349], and the unknown country is now confined almost entirely to the eastern part of the Western Division, and the west and north of the Delta Division" (p. 5). The official accounts of these explorations are given in paper-covered volumes, unprepossessing in appearance but filled with information of absorbing interest, the *Annual Reports* of the Papuan administration submitted to the Australian Parliament; more rarely in books like W. R. Humphries' "Patrolling in Papua," London, 1923, or the two works by Captain Monckton reviewed in the *Geographical Review* for April, 1924, pp. 331–332.

Judge Murray's pamphlet from which we have quoted is of value because it gives a concise summary of the work of exploration since about 1912. It is largely the record of observations of police patrols and other official missions and is illustrated with rough sketch maps. Without attempting even to summarize the topographical details presented, we may mention briefly a few of the more striking discoveries.

In the country east of the Strickland River Ryan in 1913 found what appeared to be "an abundance of coal," of which he wrote, "The surface coal is of no commercial value, but, in my opinion, it indicates that coal of a superior quality may

be met with on sinking below the surface" (quoted by Murray, "Recent Exploration," p. 35; see also J. E. Carne: Notes on the Occurrence of Coal, Petroleum, and Copper in Papua, *Bull. of the Territory of Papua No. 1*, Melbourne, 1913, reviewed in *Geogr. Rev.*, Vol. 1, 1916, p. 76). In 1922 Flint and Saunders examined the region north, northwest, and northeast of Mt. Murray, part of which had been traversed by Miles Staniforth Smith in 1910 (see *Geogr. Journ.*, Vol. 39, 1912, pp. 313–334). Here the Samberigi Valley was explored, a broad, open, cultivated hollow in the midst of imposing mountains, having an estimated area of 105 square miles and supporting a native population of 2000. Skelly and Swanson in 1917 reported natives dwelling at an altitude of 8000 feet in the Albert Mountains, a circumstance which Murray pronounces exceptional, "though altitudes of about 6000 are not unusual" (p. 24). In the eastern part of the highlands natives were seen by Jackson in 1914 carrying on "extensive burning-off operations at a height of just under 10,000 feet. It appears that they were hunting cuscus [a small marsupial], and it is probable that hunting parties occasionally visit even higher altitudes, but so far as I am aware no regular villages have been seen at a greater height than 8000 or even 7000 feet" (p. 19). British travelers frequently suffered severely from cold on the mountains. On a journey up the Strickland in 1917, Judge Murray writes (p. 37) that he saw no trace of human beings for a distance of more than one hundred miles and suggests that the natives of this district may well have exterminated each other. Commenting upon the hideous and revolting evidences of a massacre found by Baker in the same region in 1913, Murray observes that "practices such as these are not conducive to an increase of population, and perhaps it is not to be wondered at that the banks of the Strickland, when I was there, bore no trace of human existence" (p. 38).

To abolish this "almost insane craving for bloodshed" and to guide the Papuans towards the blessings and away from the evils of civilization are the outstanding problems of the local administrator. Judge Murray, who is keenly sympathetic in his understanding of the native mentality, regards these folk as "very intelligent people at a low stage of development." On their characteristics and on other problems of present-day Papua he has published an illuminating paper ("Papua of To-day," *United Empire*, Vol. 14, 1923, pp. 352–362) which should be read in conjunction with his pamphlet on exploration by all who may wish to gain some knowledge of recent events and contemporary conditions in one of the most obscure but most interesting corners of the British Empire.

The Ice Age and the Antiquity of Man in Australia. Professor David delivered the R. M. Johnston Memorial Lecture in Hobart on October 8, 1923, choosing for his subject the antiquity of man in Australia (Sir T. W. Edgeworth David: Geological Evidence of the Antiquity of Man in the Commonwealth, with Special Reference to the Tasmanian Aborigines. R. M. Johnston Memorial Lecture, *Papers and Proc. Royal Soc. of Tasmania for the Year 1923*, Hobart, 1924, pp. 109–150). Aside from the main subject, the address marks a critical point in the history of Australian Quaternary geology. Tasmania was the scene of rather intense Pleistocene glaciation. Owing to the latitude of the island, it is more likely than is the mainland of Australia to show whether or not the course of events in glacial time was in harmony with that in other intensely glaciated regions of the world. Ten years ago the Australian geologists were aware of the extent of glaciation but were too cautious to attempt correlation. Recently some work of great importance has been done by Benson, Griffith Taylor, and others; and Professor David has now revealed in his address an underlying acceptance of correlation with the broad subdivisions of the Ice Age of the northern hemisphere. This means that Australia has a time scale for the Quaternary, a matter of immense importance in archeological studies.

The past of a new country long remains a blank to its occupants. Knowledge of the Australian native is scanty enough, and archeological knowledge is of the slowest growth. Records are found at rare intervals, and even the light of geology that can be brought to bear on them is sometimes uncertain. Here, too, the recent past has been fruitful of results. Artifacts of primitive workmanship have been found in several widely separated parts of Tasmania, and the conditions of their occurrence have been carefully investigated. With these discoveries as a starting point, Professor David has reviewed all that is known of the history of man in Australia, applying the newest results in glacial geology, physiography, the paleontology of the Quaternary fauna, and anthropology. The synthetic method has been brilliantly successful. It demonstrates that man existed in Tasmania from remote antiquity and that his geological history on the mainland is longer than hitherto suspected. Admitting that the correlation is tentative, David seems to have placed his main conclusions beyond doubt. It has long been believed that the Tasmanian aboriginal was an earlier arrival than the Australian, who brought the dingo. The Tasmanian artifact from the Doone Mine near Gladstone is placed tentatively as belonging to the Würm or even to the Riss Glaciation; while the celebrated Talgai skull from near Warwick, Queensland, is placed in the Riss-Würm Interglacial Epoch and is considered by David to be Australian rather than Tasmanian. And Tasmania was undoubtedly peopled before Australia!

The paper, which is illustrated with maps, sections, etc., initiates an admirable grade of precision in Australian archeology.

MATHEMATICAL GEOGRAPHY

The Study of Maps. An attractive little book for teachers of geography is Sir Herbert George Fordham's "Maps: Their History, Characteristics and Uses; a Hand-book for Teachers" (The University Press, Cambridge, 1921). Though primarily intended to explain the elements of cartography, the volume lays much stress on the historical background. Its author conceives of the modern map as the product of development that may be traced from the earliest antiquity. While instruction in the history of maps is too advanced for elementary schools, Sir Herbert feels that the teacher should have some knowledge of this field. There is much to be said for this opinion. The need is great for unpretentious books like this, presenting other phases of geography in their historical perspective.

Sir Herbert asserts that "in the second half of the last century, map-engraving seems to have lost its beauty and originality, probably in view of the rigid uniformity of expression demanded of it." "In the choice of elements of graphic expression in relation to the pictorial features of maps there has been a gradual elimination of unsuitable signs, and the 'survival of the fittest' has produced a stereotyped uniformity—very essential in cartography, now an exact and highly-developed science." Map making in earlier days was a fine art as well as a science. Sir Herbert speaks enthusiastically of several exceptionally handsome maps of the earlier period. "Nothing," he writes, "attains to the beauty of the two large maps of the district and bay of Naples by Rizzi-Zannoni . . . of the end of the eighteenth century. The surface of the map is of marvellously minute execution, the panoramic representation of the coast-line on one of these maps is a lovely piece of work, and the borders and other ornamental features are superb."

Otherwise admirable as this little book is, there are two matters which cannot be passed over.

The invention of the contour line for representing relief was one of the most important contributions to the progress of modern cartography. On page 47 Sir

Herbert makes the misleading statement that contours "were first adopted in France, on the suggestion of Laplace, in 1816." They had been employed, however, in mapping the bed of a river channel as early as 1728. Dupain-Triel's map of France with contour lines was published in 1791. The method was certainly well known, even if it had not been widely used, before 1816. (See Anton Steinhauser: Beiträge zur Geschichte der Entstehung und Ausbildung der Niveaukarten, sowohl See- als Landkarten, *Mitt. K. K. Geogr. Gesell. in Wien.*, Vol. 2, 1858, Abhandlungen, pp. 58–74; reference on p. 60; and Henri Zondervan: Allgemeine Kartenkunde, Leipzig, 1901, p. 53.)

The other point is the omission of any discussion of the problem of representing the spherical surface of the earth on a flat surface, an omission that was probably intentional in view of the difficulty and technicality of the subject. It is, nevertheless, one of the major problems of cartography. Even if they may not be expected to master the mathematical details, we cannot but feel that all teachers and students should know at least that this problem exists and should know something of the efforts that have been made toward its solution. Sir Herbert's treatment passes it by altogether.

Besides the book described above, Sir Herbert has published during the last twenty-five years a number of studies in the "cartobibliography" of various regions and types of map. Among the more recent of these is a note in the *Bulletin de la Société Royale Belge de Géographie*, Vol. 47, 1923, pp. 35–43, in which he emphasizes the historical importance of old maps and the desirability of their systematic listing. References are here given to other papers by Sir Herbert. In an address delivered at the University of Manchester on the "Evolution of the Maps of the British Isles" (The University Press, Manchester, 1923), he outlined very briefly the outstanding events in the history of cartography in the British Isles prior to the work of the Ordnance Survey.

PHYSICAL GEOGRAPHY

Seasonal Abnormalities of World Weather. Dr. Gilbert T. Walker's paper, "A Preliminary Study of World-Weather," is eighth in the series "Correlation in Seasonal Variations of Weather" of the memoirs of the Indian Meteorological Department (Vol. 26, Part IV, Calcutta, 1923). Dr. Walker has gone over in detail all previous work on the subject and has brought up to date, with the most recent records available, a great many of the seasonal weather correlations worked out earlier by himself and others. He finds in many cases that apparently excellent correlations indicated by 20 or 30 years' records do not show when 40 or more years are used. His paper demonstrates how important is caution in interpreting even high correlation coefficients when these coefficients are no more than double or treble the probable error.

Dr. Walker first discusses in some detail the correlations between sunspots and pressure, temperature, winds, cloud, and rain. He finds that with an abnormally large number of sunspots annual pressure is affected irregularly; annual temperature is, in general, lowered particularly in the tropics; the effect on winds is uncertain; cloudiness in India is apparently slightly increased, except in the hot weather, April and May; and rainfall is affected irregularly, heavier rain, in general, going with lower pressure.

A comparison of temperatures at some stations in India with values of the solar constant has been made by Dr. Walker for the summer months 1905, 1906, and 1908–1920. He finds that ". . . apart from rainfall the solar constant has a corr. coeff. of about +.30 with temp." The coefficients for some other tropical and subtropical stations run about like that of India, +.3 to +.4, values not large

enough to be more than suggestive. Dr. Walker's general conclusion is that "for explaining the weather abnormalities of the seasons the variations of the solar radiation are inadequate, and we must seek the reasons in the previous distribution of seasonal features over the earth. In this conclusion we disagree with the widely prevailing idea that such abnormalities are an immediate consequence of changes in the heat given out by the sun. As a definite example I know of nothing in solar physics to explain without reference to previous terrestrial conditions the contrast between the biggest Indian monsoon on record in 1917 and the monsoon in 1918 that has only been surpassed in scantiness twice in the last sixty years."

For discussing relationships between centers of action of the atmosphere, Dr. Walker chooses 15 pressure centers and 6 precipitation centers. The North Atlantic high is divided into two parts, represented by the pressures at Punta Delgada, Azores, 1875–1921, and Charleston, S. C., 1875–1919. Of the rainfall centers only those of the peninsula of India and Java are discussed at length. For each of the 15 pressure centers and each of these two rainfall centers Dr. Walker presents the correlation coefficients with all the others for winter and for summer, for the same season, and the seasons two quarters before and after. These represent, truly, a prodigious amount of tabulation and computation. For all regions except the North Pacific or Alaska low, Honolulu, the south tropical Pacific (Apia, Samoa), and the southern low (Laurie Islands, S. Orkneys), the data cover homogeneous periods of about 30 to 46 years. Correlation coefficients, therefore, of .4 or greater are probably significant except for the centers mentioned.

The atmospheric centers of action directly affecting the seasonal weather of North America are not only interrelated more or less strikingly at the same season but also have their variations indicated to some degree half a year in advance at distant centers. South Alaska and Hawaiian pressures are inversely correlated (—.71 (?) in winter), just as are those of Iceland and the Azores (—.54 in winter) and Iceland and Charleston, S. C. (—.33 in winter). Rather unexpected are the large correlations between Charleston pressures and those of Port Darwin (N. Australia) and Northwest India, both —.52 in winter, and between Charleston pressures and those of Northwest India and St. Helena, —.51 and +.49 in summer. The correlation coefficient —.36 between the pressure of Central Siberia, June to August, and that at Charleston the following December to February may be significant. "We can perhaps best sum up the situation by saying that there is a swaying of pressure on a big scale backwards and forwards between the Pacific Ocean and the Indian Ocean, and there are swayings, on a much smaller scale, between the Azores and Iceland, and between the areas of high and low pressure in the N. Pacific: Further, there is a marked tendency for the 'highs' of the last two swayings to be accentuated when pressure in the Pacific is raised and that in the Indian Ocean lowered."

As a result of Dr. Walker's studies it seems to have become possible not only to increase the accuracy of the long-range forecasts made of the monsoon rainfall of India but also to make these forecasts as early as the end of February preceding the summer monsoon and even to make forecasts of the winter rains. Dr. Walker is now engaged in closer studies by months of the most significant correlations.

These world-wide reactions of the weather are evidently closely connected with the slowly moving ocean currents in which solar or wind-made temperature abnormalities persist for months. The fact that seasonal weather abnormalities in different parts of the world show stronger relations among themselves than with solar changes need not cause us to relegate to a minor position the study of solar variations and terrestrial weather changes. The solar changes may from time to time strengthen and thereby maintain the reactions between terrestrial pressure centers which otherwise might become appreciably weaker.

CHARLES F. BROOKS

Mediterranean Climates of Eurasia and the Americas. H. A. Matthews has nine pages in the *Scottish Geographical Magazine* for May on the *dissimilarities* between the Mediterranean climates of Eurasia and those of the Americas, stressing the upwelling cold waters on American west coasts, which Europe lacks, and with them the striking coolness of American west-coast summers; and likewise the penetration of the Eurasian Mediterranean so far into the subtropical lands, which goes with the east-west structure of the old Mediterranean ridges, where America has north-south lines of plateau and ridge.

Corresponding differences in the winds and in the degree of prevalence of winter rains are pointed out.

While indicating the way in which these contrasts modify the analogies, the author makes it clear that he regards the similarity of all the west-facing subtropical shores as the major character.

MARK JEFFERSON

HUMAN GEOGRAPHY

Geography in Literature. Some men of letters are endowed with a highly developed geographical instinct. As writers, they have trained themselves to visualize even more clearly than the professional geographer those regional elements of the earth's surface most significant to the general run of humanity. Geographers, however, have devoted but little attention to this fascinating subject of geography in literature. H. R. Mill's useful "Guide to Geographical Books and Appliances," London, 1910, contains a chapter in which the plea is made that in educational value the "geographical novel" be recognized as on a par with the historical. Mill distinguishes between the multitude of works of fiction revealing merely "local color" and those that are distinctly geographical, and he briefly discusses some of the best among the latter. In 1920 Miss D. Wharton edited for the Leeds Branch of the British Geographical Association a "Short List of Novels and Literary Works of Geographic Interest," intended to "help make the world really alive to students of geography." This list is suggestive, if of somewhat uneven quality.

Students of the history and trends of literature, on the other hand, have gone into the matter in no little detail, especially in relation to the local-color movement of the last half century. An entertaining chapter on the quest for local color will be found in W. P. James' delightful book, "The Lure of the Map," London, 1920 (reviewed in *Geogr. Rev.*, Vol. 11, 1921, p. 160). Local color is an evasive quality, revealing itself in different hues to different seekers. It exists, none the less, and the geographer should be among the last to disdain its existence. A colorless regional monography falls short of the geographical truth.

Some understanding of the local-color movement in the United States may be gained from Robert L. Ramsay's "Short Stories of America," Boston, 1921. This volume, edited primarily for classroom work in English composition courses, includes a selection of sixteen short stories illustrative of various ways in which local color may be depicted. Dr. Ramsay shows his appreciation of geographical values by partitioning the United States and Alaska into five major divisions and twenty-five subordinate "local-color states" and by drawing their boundaries on a map (Fig. 2). These boundaries do not coincide with those of political states but mark off from one another wholly independent regions each one characterized by a sufficiently individualistic type of life to have given rise to a distinctive type of story. There is no slight measure of correspondence between Dr. Ramsay's literary provinces and the physiographic, climatic, and vegetational regions of the geographers.

The map also shows certain neutral zones, which "probably because of their transitional location . . . have as yet attracted but little attention from local colorists." Dr. Ramsay's book closes with a series of reading lists giving the titles of seventy-five stories arranged according to the twenty-five "local-color states" which they illustrate.

A similar compilation for France, intended, however, not for the student of composition but rather for the mature general reader, is Septime Gorceix's "Le Miroir de la France: Géographie Littéraire des Grands Regions Françaises." Paris, 1923. Here, instead of short stories, a selection is made of excerpts from novels, poems, essays, and descriptions, chosen for the poignancy with which they depict the various *pays* and cities of France. The *pays* are defined in the preface by Jérôme and

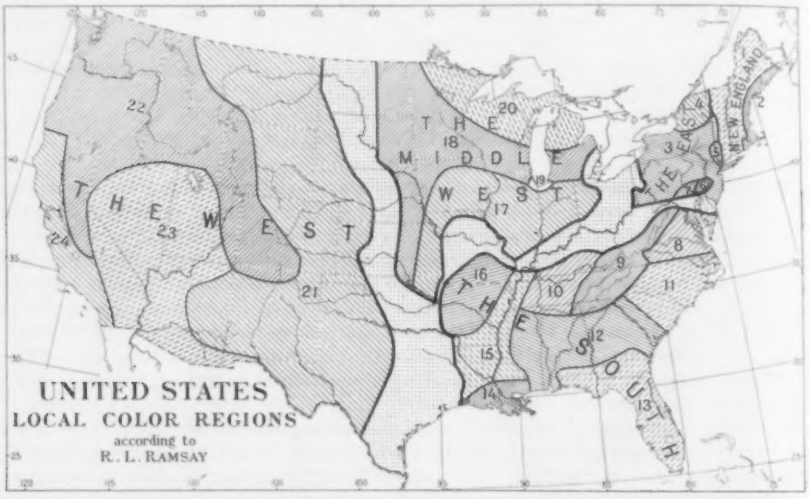

FIG. 1—Local color regions of the United States according to R. L. Ramsay. 1, Old New England; 2, the New England Coast; 3, the Middle East; 4, Upper New York; 5, New York City; 6, Philadelphia; 7, the Pennsylvania Dutch; 8, the Old Dominion; 9, Appalachia; 10, the Blue Grass; 11, the Middle South; 12, the Lower South; 13, the Swamp Region; 14, the Creole Country; 15, the River Country; 16, Canebrakes and Ozarks; 17, the Corn Belt; 18, the Wheat Belt; 19, Chicago; 20, Mackinac; 21, the Cattle Country; 22, the Mountain West; 23, the Arid West; 24, California and the Old West; 25 (not shown), Alaska; unnumbered stippled areas, neutral zones.

Jean Theraud as "ces nappes homogènes par le sol, le sous-sol, le mode de culture et de propriété, l'habitation et l'aspect particulier qu'y prend la vie des plantes, des animaux et des hommes." They are the popular divisions of the countryside. Argonne, Woëvre, Brie, Sologne, Limagne, etc., and their designations as employed by the peasants are often older than the names of the provinces of the *ancien régime* or of the medieval feudal territories. The selections in Monsieur Gorceix's pleasing book are arranged according to the major divisions of the country, and a map is provided showing these divisions and the various *pays*. The compiler introduces each section of the volume with a brief account of the principal geographical elements of the region under consideration and a bibliographic note on the outstanding geographical monographs. The book presents an admirable combination of scholarly treatment with genuinely subjective and colorful word painting, a form of combination in which the French are masters.

GEOGRAPHICAL NEWS

Geography at the British Association Meeting at Toronto. The ninety-fourth meeting of the British Association for the Advancement of Science was held at the University of Toronto from August 6 to August 13. In contrast to the American A. A. S., geography is represented by a separate section (E) in the British Association. This leads to a more strictly geographical program, geological topics being discussed in the geological section (C).

Twenty-three papers were read in the four morning and two afternoon sessions devoted to the program. The outstanding paper by reason of its truly geographical analysis of the problem was the one by Professor P. M. Roxby of the University of Liverpool on the Distribution of Population in China. Based on the census made in 1918 by the Survey Committee of China, a missionary organization, maps were shown which for the first time represent the essential facts of population distribution in China. This distribution was discussed in relation to the natural divisions of the country, and the regional outlook of the main nuclei of population was described. The probable rôle of the Lower Yangtze region, and especially the Hupeh Basin, in the political consolidation of the Chinese people was then pointed out, with a possible change of the capital from Peking to Hangchow or Nanking—a consolidation in which the great north-south railroad, when completed, will of course play an important part. Professor Roxby's paper will appear in full in a forthcoming number of the *Review*.

The presidential address, by Professor J. W. Gregory of the University of Glasgow, dealt with Inter-Racial Problems and White Colonization in the Tropics. After a survey of conditions in the different parts of the world where the white and colored races live together—in racial fusion in South America, in co-resident distinctness in the United States, in racial segregation as desired for South Africa—tropical colonization and the future of Australia were discussed.

Several other papers dealt with aspects of human geography. Miss Ellen C. Semple spoke on the Influence of Geographic Conditions on the Ancient Mediterranean Religions, pointing out how the importance of rainfall is reflected in the persistence of the worship of a rain-giving deity or saint. Dr. H. H. Laughlin of the Eugenics Record Office of the Carnegie Institution discussed Immigration from a Biological Point of View, with special reference to the policy of the United States. Mr. H. L. Seymour of Toronto, who has been associated with Mr. T. Adams, now of the Committee on the Plan of New York and Its Environs, read a paper on Some Problems of Urban Growth in America in which the principles of town planning were elucidated.

A group of papers provided a valuable survey of the contributions to the geography of Canada made by various Canadian government bureaus and other agencies. Mr. E. M. Dennis told of the Work of the Topographical Survey, Mr. W. H. Boyd of the Geological Survey's Part in the Topographical Survey, Mr. A. M. Narraway of the Practical Application of Aerial Photographs to Surveys in Canada, Mr. W. H. Herbert of the Work of the Magnetic Survey, a colleague of Mr. N. Ogilvie of the Work of the Geodetic Survey, and Dr. W. Bell Dawson of the Work of the Tidal Survey. An important development announced in these papers is the forthcoming unification of the mapping bureaus of the Canadian government. This will bring about the extension to easternmost Canada, for which the so-called Topographical Map, which does not show relief, has been the standard, of the type of mapping now carried on in the prairie provinces and in Old Ontario and Quebec and illustrated respectively by the excellent Sectional Map published by the Topographical Survey and the one-inch-to-the-mile map published by the Department of National Defense, both of which now represent relief in contours. Mr. D. W. McLachlan, engineer in charge of the St. Lawrence Ship Canal, spoke on the Pro-

posed Improvements of the St. Lawrence and Great Lakes System for Power and Navigation. Lake ports will be brought nearer to the markets of Europe by the improvements under way. Dr. R. M. Anderson read two papers resulting from his connection with the Canadian Arctic Expedition of 1913–1918. One described the scientific work of the Southern Party (with this topic readers of the *Geographical Review* are familiar: see Vol. 4, 1917, pp. 241–266); the other discussed the Present Status and Future Prospects of the Larger Mammals of Canada. In this connection mention should be made of a paper announced by Professor J. F. Unstead of Birkbeck College, London, not read on account of his absence through illness, on the Natural Resources and Economic Future of Canada. It was proposed to express the result of full utilization of the economic resources in each of the natural regions of the country in terms of the number of people who could be supported. This group of papers was supplemented by an exhibit illustrating the geographical activities of the Canadian government bureaus.

Several papers dealt with other regions or other aspects of regional geography. Mr. O. H. T. Rishbeth of the University of Southampton spoke on Some Geographical Consequences of the Geology of Australia, dwelling mainly on the fundamental problem of water supply. Mr. W. L. G. Joerg discussed Human-Use Versus Natural Regions, With Special Reference to North America. Mr. A. Stevens of the Department of Geography of the University of Glasgow gave an intimate picture of the hard life of the crofters on the Hebridean island of Lewis. Major C. Christy gave traveler's glimpses of conditions along the Cape to Cairo railway, 5000 of whose 7000 miles are in operation and along the route of which there remains only a 100-mile gap (between Nimule and Rejaf) without boat or rail communication.

Physical geography was represented by two papers and by a joint discussion with Section C on Changes of Sea Level in Relation to Glaciation, Continental Shelves, and Coral Islands in which Professors R. A. Daly, W. M. Davis, and A. P. Coleman took part. A paper illustrated with exceptional lantern slides was Dr. Vaughan Cornish's on Wind, Waves, and Swell on the North Atlantic. Professor W. H. Hobbs of the University of Michigan called attention to the fact that meteorologists in their descriptions of the circulation of the atmosphere do not seem to have taken sufficient account of the great anticyclones prevailing over the glacial ice caps of Greenland and the Antarctic Continent.

Three other papers completed the geographical program. Mr. John Bartholomew, head of the Edinburgh Geographical Institute, the well-known map publishers, spoke on Modern Developments in the Use and Construction of Maps. An item to which he made reference is of interest to all who are familiar with the inadequacy of the existing maps in this field, in that an up-to-date population density map of the British Isles is being prepared by a committee of British geographers. Mr. J. H. Reynolds described the Work of the Permanent Committee on Geographical Names for British Official Use. Dr. Marion I. Newbigin discussed the Training of the Geographer in Great Britain.

A number of papers presented before other sections were also of interest to geographers. Of these it seems unfortunate that, because of conflicting time schedules, the geographers were unable to hear the paper before Section L (Education) on the Teaching of the History and Geography of the British Empire by Professor G. M. Wrong of the University of Toronto, in view of Professor Wrong's sympathy with the geographic viewpoint in history. Before the same section Mr. Ernest Young spoke on Modern Tendencies in the Teaching of Geography. In Section A (Mathematical and Physical Science) meteorological topics were discussed by Sir Napier Shaw (If the Earth Went Dry) and Sir Frederic Stupart (The Variableness of Canadian Winters). Before Section D (Zoölogy) Professor A. G. Huntsman read a paper on the Circulation of Water off the Canadian Atlantic Coast. Dr. A. C. Haddon presented a suggested Arrangement of the Races of Man before Section H

(Anthropology). Before Section F (Economic Science and Statistics) Mr. G. Udny Yule discussed the Population Problem from the Standpoint of the Pearl and Reed Law of Growth, and Professor C. D. MacIver spoke on Civilization and Population. Before Section G (Engineering) and K (Botany) a number of papers were read dealing mainly with the economic resources of Canada: on the water powers, by Mr. J. B. Challies, Director of the Water-Power and Reclamation Service; on the Development of the St. Lawrence for Power and Navigation, by Mr. R. S. Lea; on Forest Utilization in Canada, by Mr. R. D. Craig; on the Problem of the World's Timber Supply, by Mr. Craig and Mr. F. Storey.

Several excursions were arranged for during and after the session. Of those under the auspices of Section C (Geology) a local excursion to study glacial phenomena in the Toronto district, mainly in the Don Valley and at Scarborough Heights, and an excursion to Niagara Falls and the Niagara Escarpment at Grimsby were generally attended by the geographers at the meeting. Excursions of geographical interest were also made by the Engineering Section in Toronto harbor and to the Welland Canal and the Queenston hydro-electric plant. But the most interesting of all was the transcontinental excursion across Canada after the meeting, August 17 to September 3. The route, which was traveled in two special trains, led to Vancouver by the Canadian National Railway and back to Toronto by the Canadian Pacific Railway. Technical guide books were issued: for the Niagara excursion, by Professor A. P. Coleman; for the transcontinental excursion, by Mr. James White. In addition a valuable handbook of Canada discussing the history, geography and economics of the country was issued, which forms a counterpart and addition, as it were, of the similar publication issued on the occasion of the previous meeting of the British Association in Toronto in 1897.

Professor Douglas Johnson's Exchange Professorship in France. During the academic year 1922–1923 American geographers had the pleasure of welcoming Professor Emmanuel de Margerie in his capacity as Exchange Professor in Engineering and Applied Science to the Universities of Harvard, Yale, Columbia, Cornell, Pennsylvania, Johns Hopkins, and the Massachusetts Institute of Technology. Last year (1923–1924) a return visit to France was made by an American geographer, Professor Douglas Johnson, representing the same institutions.

During the winter Professor Johnson visited the Sorbonne and the Universities of Dijon, Nancy, Rennes, Bordeaux, Montpellier, Algiers, Lille, Strasbourg, Clermont-Ferrand, Lyons, and Grenoble, delivering altogether more than seventy formal lectures as well as making many shorter speeches and holding various conferences with students, always in the French language. In each university he gave a number of lectures of general interest on such topics as American Rivers, Glacial Sculpture in America, the Atlantic Coast, and the Grand Canyon of the Colorado. In addition he gave a number of more technical lectures for the benefit of students chiefly or technical engineers, on such subjects as the Submarine Topography of the Gulf of Maine, Rectilinear Shore Lines of New England and Acadia, the Application of Physiography to Legal Problems. The conferences with the students were more informal talks in connection with the study of map interpretation, in which American maps were chiefly used. At the request of the French Army a special address was given before the officers of the Topographic Branch, French maps being used as a basis for the discussion.

At many of the universities interesting excursions were planned, the most extensive being a trip from Algiers, across the Atlas, into the Sahara to the present end of the railroad line at Tuggurt.

The University of Nancy awarded to Mr. Johnson the special medal of the university. The Geographical Society of Bordeaux made him an honorary member

of that organization, and the University of Grenoble conferred upon him the degree of Docteur *honoris causa*.

Certain of the lectures will be published at an early date under the title "Paysages Americains et Problèmes Géographiques."

Obituary

Mr. George Kennan, well known as an explorer, writer, and lecturer, died at Medina Depot, N. Y., on May 10 in his eightieth year. Mr. Kennan's most interesting geographical work arose from his connection with the project of an "overland" telegraph route between Europe and America via Bering Strait, an undertaking abandoned on the successful laying of the transatlantic cable. In 1865 he was sent to Siberia to engage in reconnaissance work over a part of the proposed route. His surveys included the previously unexplored region between the Gulf of Gizhiga (on the Okhotsk Sea) and the Anadyr River. The narrative of the expedition is told in "Tent Life in Siberia" (1870; revised edit., 1910). In 1870–1871 Mr. Kennan explored the eastern Caucasus. In 1885–1886 he investigated the Russian exile system, publishing his findings in a two-volume work "Siberia and the Exile System" (1891). Among his later writings mention may be made of his graphic account "The Tragedy of Pelée" (1902).

Mr. Kennan was a Life Fellow of the American Geographical Society and a contributor to the earlier volumes of the Society's *Journal*. His sustained interest in the Society is manifested in the bequest to the institution of his large collection of lantern slides.

GEOGRAPHICAL REVIEWS

Two Works on Political Geography

Alexander Supan. **Leitlinien der allgemeinen politischen Geographie: Naturlehre des Staates.** 2nd edit., edited by Erich Obst. viii and 199 pp.; maps, diagrs., ill., index. Vereinigung wissenschaftlicher Verleger, Walter de Gruyter & Co., Berlin and Leipzig, 1922.

In Supan's great work on the population of the earth the method was rigidly statistical. The second stage of his development was marked by the production of two books, "Grundzüge der Physischen Erdkunde" and "Die Territoriale Entwicklung der Europäischen Kolonien," in which the same quality appears in high degree. There are also exhibited the rigid tests and masterly restraints that we expect to find in a truly scientific production by a mature scholar. His last work (published posthumously) was in the field of political geography, and here there was freer play for the imagination and especially for opinion, and, we regret to add, for prejudice. The times had changed: he stood on the threshold of the new, or post-war, world as a German and saw wreckage everywhere. The despair that he felt is conveyed to these pages, and it is but just to his memory and to his earlier work that the basis of it be remembered when reading some of the strictures that follow.

The trouble with Supan's philosophy lies in his almost instinctive search for a "system" wherein should be rationalized the facts comprised in political geography. It is as if he searched for laws akin to those that govern the physical world. It is characteristic of the German school of political geography that its logic so often rests upon mere classification, and the descent is not far from this to *obiter dicta* and the worship of ritual and mummery. There is much that is excellent in Supan's book, and to this we shall presently give full credit. Here, the point of emphasis is the spirit and logic of the work as a whole. The worst example of the illogical is in the first paragraph of the first page: institutions are the means of achieving civilization; the state furnishes the means of existence of such institutions; the state is the foundation of civilization or culture; one cannot think highly enough of the state. The alternative to this policy is individualism whose baneful effects he finds illustrated in communistic Russia. Such an eye is too largely filled with European, i. e. near-by, examples. Such a philosophy seeks to draw out leviathan with a hook. With that history those things may be expected, but what of the fresh examples overseas? A large part of the world is politically in the pioneering stage; its philosophy is certainly more individualistic and democratic; is it so near the abyss as Europe today? When Supan turns scientist his thought is always illuminating; witness especially his distinction between the active and passive spaces and his emphasis upon the necessity of comparing active with active when we compare two nations, otherwise we do not apply the proper shrinkage, for example to northern Canada and Russian Siberia. He rightly criticizes Ratzel's overemphasis of space alone whereas it is people, nations, societies, and cultures that give space its chief geographical significance. He draws a startlingly clear picture of the flowing, not the static, life of boundaries. Even if by some process of necromancy boundaries were adjusted on all frontiers to national needs and if proper economic advantages and political scope were given to every nation, the equilibrium would last but for a moment, just as in the case of an equal distribution of wealth among a whole population. Birth rates differ, industries and natural resources differ, vital energy and initiative differ. Inequalities arise from these and other causes, and strife and shifting boundaries once more occur. There is virtue in the argument of "organic bound-

aries" and the philosophy of *Lebensraum*, but they are open to abuse like the arguments based on history and military necessity of which much use was sought to be made at the Paris Conference of 1919. Curzon's argument regarding the protection of the Indian frontiers is the inevitable one employed in advocating "natural frontiers" and in following a purely territorial policy as opposed to a national policy. It is the large states, curiously enough, that require the most elbow room and seek most aggressively for increase of space and power often to the point of weakening the central state and government. In all times, large and small states have existed on account of differences in topographic layout, resources, stages of development, and the like. The sea and the desert give geographical position its greatest force and meaning, while mountains were early reduced in importance on account of the passes at the heads of deep valleys, though they still exercise a measurable and often a strong political influence, as is shown in the case of Tibet.

The historical rôle of great cities is discussed together with their function as political centers and even as states before land and territory had political value. What a far cry is this from the condition of the world today, when even the empty spaces are no longer non-political. Great Britain in Antarctica, France in the Sahara, and all great powers with respect to the sea, illustrate the generalization. Nonpolitical areas are all but nonexistent. Border belts have thinned to line boundaries. Neutral zones, like that between Norway and Sweden, have almost disappeared.

Such are a few of the objective and impersonal illustrations from political geography in which the text abounds. Interspersed are many examples of the philosophy to which we referred at the beginning. The author disparages Woodrow Wilson among other things for being led astray by pseudo-nationality as illustrated by Czechoslovakia; but who should absorb the Czechs if there were no Czechoslovakia he does not say. Is it only "pseudo" when Germans are absorbed? The so-called "colonial quotient" (pp. 22–23) appears to be a barren basis of argument to all but a Germany bereft of her colonies. "The Englishman regards himself as the divinely appointed Lord of the Earth," is a sentence which an American scholar might speak in an unguarded moment, but he would hardly write it. The same is true of the reiterated charge that France is "atheistic" and "sterile." Self-determination fits Supan's idea of the state as at once the mother and protector of all culture; and it is a solace for a Germany shorn of territory, east and west, that is peopled by Germans. Would it have been a part of his "system" if German arms had extended their sway to the outer marches? Pan-Slavism, Pan-Germanism, Pan-Turkism, and Pan-Islamism have all gone their way, and he thinks they are an illusion but that connationality has possibilities. Asia for the Asiatics and Africa for the Africans is a policy he approves, but in Europe it is quite different; and the book ends on a bitter note that refers particularly to the loss of the German colonies as a violation of any possible economic system. He inquires meaningly, Cannot Slavs and Germans unite as a counterpoise to Anglo-Saxons, Latins, and Japanese?

FRIEDRICH RATZEL. **Politische Geographie.** 3rd edit., revised and enlarged by Eugen Oberhummer. xv and 626 pp.; maps, indexes. R. Oldenbourg, Munich and Berlin, 1923. $3.50. 10 x 7 inches.

Where the old political geography was constituted by an unorganized assemblage of statistical facts Ratzel made a scientific inquiry into the relations existing between land and state, or between geography and national policy. A quarter of a century since its first publication (1897) there appears the third edition of Ratzel's pioneer effort to lift political geography to the rank of a science. His work starts from a geographical conception of the state, "because the state, in all its stages of political evolution, maintains a constant and necessary connection with its land." This national territory has geographical location, area, and climate; it embraces a group of

natural features; it is delimited by boundaries drawn on the earth's surface; and it sustains definite relations with its political neighbors. To this complex of geographic conditions the state adjusts itself in the course of its development, exploiting its natural advantages to build up political power and to overcome the handicaps of its environment.

The study of this land-rooted state requires the "geographical sense" which has always characterized practical statesmen, like Disraeli and Thomas Jefferson, and which has distinguished whole nations, like the British. In such it is called politico-economic foresight, political instinct, or imperialistic policy; but at bottom it means a correct estimate of the geographic basis of national power, an eye for the main geographic chance. This "geographical sense" contributes to the evaluation of political policies and the understanding of many historical events. Ratzel formulated guiding principles and reduced them to a scientific system. His "Political Geography," therefore, was such as to make a strong appeal to statesmen and historians as well as to geographers. Such an appeal it did make, significantly enough, to the practical English, who might well have adopted it as the Bible of their foreign policy. In Germany it was more appreciated by students of political science than by the geographers; for these, committed to physical, economic, and commercial geography as the orthodox branches of their subject, frowned upon the new science as nonconformist. Hence for some twenty years it stimulated little or no effort among German geographers to till the promising field. Then the World War came and by its cataclysmic forces thrust into prominence innumerable concrete problems of political geography, which set up a new demand for scientific political geography. Geographers like Hettner, Supan, and Schlüter reversed their previous positions and welcomed the subject into the inmost circle of the scientific geography. In 1918 appeared the first edition of Supan's "Leitlinien der allgemeinen politischen Geographie," with a preface assigning to political geography a new importance in order to counterbalance the preponderant development of geography on the physiographic side. Articles and treatises by Partsch, Karl Dove, Hettner, Schlüter, Walter Vogel, Dix, Sieger, and Kjellén, the latter a follower of Ratzel, appeared in rapid succession.

The new edition of Ratzel's work is a response to the new demand. Some redundant material has been eliminated from the original copy in the present volume, which is enriched, moreover, by a scholarly historical sketch of political geography by the editor. In a footnote Professor Oberhummer expresses his regret that he has been unable to include in the sketch the recent foreign contributions to the subject, because he did not have access to the books.

ELLEN CHURCHILL SEMPLE

GEOGRAPHY AND NATIONALITIES

ARNOLD VAN GENNEP. **Traité comparatif des nationalités.** Vol. I, **Les éléments extérieurs de la nationalité.** 228 pp.; index. Payot & Co., Paris, 1922. 8 fr. 9 x 6 inches.

The problem of nationality and of nationalism, or the aggressive manifestation of the spirit of nationality, is one in regard to which there has been an infinite amount of vague thinking and loose writing. The book under review gives satisfaction because it is based upon the observation and comparison of facts rather than upon prejudice, sentiment, and abstract theory. The author proceeds inductively: through the systematic examination of the various elements and expressions of nationality he would arrive at some generalizations regarding its nature and the manner in which it may be guided into channels conducive only to the good of humanity. In the present volume he deals with the "external symbols" of nationality; the second and third will be devoted to a far more difficult subject, "the in-

ternal elements and factors of nationality" and "the general laws which govern its birth and control its evolution." Let us hope that the conclusion of the work will measure up to the first part in scholarship and logical clarity of presentation!

The problem of nationality is often thought of as exclusively one of history, or of political theory, or of mass psychology. Van Gennep recognizes the immense importance of the geographical factor, and his footnote references show that he is thoroughly versed in recent geographical thought upon the subject.

Among the external symbols of nationality some are temporary and accidental, changing with time and custom as, for instance, a characteristic style of tattoo or costume, of flag or alphabet, of house form or village plan. More significant, however, are the semi-permanent symbols: language and territory.

Language is often, though not invariably, a criterion for the determination of nationality. The recent history of Central and Eastern Europe shows the lengths to which nationalism may go in an effort to suppress a language symbolic of an alien and potentially hostile nationality. Very illuminating is Van Gennep's discussion of official methods of perverting and misinterpreting linguistic and other statistics.

The most nearly permanent as well as the most impressive of all the symbols of a nationality is the territory it occupies. This territory is, of course, not necessarily the same as the territory of a political state or of a linguistic area. "In order that a given territory may fully acquire its symbolic value, one should know where it ends." In other words, the problems of the "nationalitary frontiers"—to use a neatly coined adjective employed by Van Gennep—and of their relations to linguistic, political, economic, strategic, and natural frontiers are of major importance in the study of nationalities. They are essentially geographical problems.

Particularly interesting in view of the theoretical nature of many geographical studies of these matters are Van Gennep's observations on so-called "natural frontiers." How far can it be asserted that the various types of human frontier actually correspond to such natural features as the crest lines of mountains, water partings, or rivers? Is there a general law indicating that they tend so to correspond? The author answers both of these questions in the negative. Detailed and critical examination of the facts seems to show that only in exceptional cases do such coincidences occur. A great river tends rather to unite than to separate the people dwelling on either side, and a great mountain range from the point of view of nationality and language may be regarded as a "dorsal spine" rather than as a barrier. The theorists who seek a direct, necessary, causal relation between the areas occupied by nationalities or language groups on the one hand and natural regions on the other confuse "two series of facts essentially independent."

A French Series on "The Evolution of Humanity"

Edmond Perrier. **La terre avant l'histoire: Les origines de la vie et de l'homme.** xxviii and 414 pp.; maps, bibliogr., index. (L'Évolution de l'Humanité, Vol. 1.) La Renaissance du Livre, Paris, 1920. 15 fr. 8 x 6 inches.

Jacques de Morgan. **L'Humanité préhistorique: Esquisse de préhistoire générale.** xix and 330 pp.; maps, ills., bibliogr., index. (L'Évolution de l'Humanité, Vol. 2.) La Renaissance du Livre, Paris, 1921. 15 fr. 8 x 6 inches.

L'Évolution de l'Humanité is the title of an interesting series which hopes, in 26 or more volumes, to give its readers a sketch of evolution and principally of human and social evolution. The printing and paper are the simplest and cheapest so that the price may be as low as possible. It is felt that the discussion of evolution is closed and the idea definitively established and that one may venture upon a kaleidoscopic review in preparation for further discussion of the steps and the

processes of evolution. The first volume of the series bears the great name of the Professor of Comparative Anatomy at the Natural History Museum at Paris. It attempts a sketch of evolution up to the appearance of man, and the biological reader will follow with great interest and frequent agreement the thoughts of the famous author about different groups of animals and plants. At the same time he may well regret that the attempt was made to compress all into one volume and that the opportunity was not taken to get some one like M. de Margerie to write of the evolution of the earth and the succession of floras and faunas in their relation to earth changes. Those who know de Margerie's version of Suess will feel that a summing up by him might have illuminated many points perforce left vague or unnoticed. The discussion of the history of climate, again, is not of great value and, as the manuscript was largely written in 1914, does not take into account the contributions either of C. E. P. Brooks or of Huntington to this difficult but most fascinating subject. On the other hand, the wide and ripe knowledge of forms of life that Perrier has amassed is here utilized to give a sketch that, with occasional references to some standard biological textbook, may become valuable and illuminating even to the non-specialist.

The general succession of ideas in the book starts with a very short notice of the birth of the earth and the transformations of land masses and attendant climatic changes. Then it surveys early forms of life and the plans on which organisms are built. In concluding this section the author notes the fragmentary nature of the life of continents, abysses, and open seas and the large proportion of that life which shows high specialization and which seems to belong to fairly recent types, leaving the reader to infer the importance of the shore zone as a home of early life and the spread of forms of life from it in all directions. The second section surveys life in the Paleozoic, Mesozoic, and Cainozoic periods and sketches very briefly the origins of man. Many of the opinions expressed are open to dispute, but that type of dispute would concern more especially the zoölogist. In spite, however, of points here and there which are either disputable or left hazy, the reader will admit that Perrier has executed a *tour de force* and will enjoy this work.

De Morgan's volume, the second in this series, shows a better proportion of its parts than do some other books on prehistory for, in the first and chronological section the Old Stone Age is not given much more space than the subsequent periods (Neolithic, Bronze, and Early Iron Ages) down to the opening of historic time. The second section discusses dwellings, the food quest, clothing, and ornament. The third deals with the intellectual development and interrelations of peoples.

The book has considerable interest as being the work of one who has been dealing with prehistoric problems for many years; but it could hardly be expected to be fully up to date, and one notices many cases of omission or imperfect use of authorities. The study of prehistoric times is now developing so fast and in so many countries that it is difficult for even the most active mind to keep pace with results.

The table showing the relation of our hypothetical Paleolithic "periods" to phases of the Ice Age given by de Morgan is based on that published by Boule in 1906, since when much has been worked out as readers of *Man* for 1921–1923 will know. The maps of distributions of Paleolithic cultures are open to discussion in some points, while in others the difficulty and the disparities between de Morgan and other authorities arise from uncertainties which warn us that even the accepted classifications may be modified. The Neolithic Period would need a fresh treatment following on the work of Ischer and of Åberg, not to mention others, while the Bronze Age is being considered anew, thanks to the vast catalogue of Bronze Finds compiled for Great Britain in recent years under the direction of H. J. Peake and now in the library of the Society of Antiquaries of London. The volume, in fact, stands as a closing chapter of the earlier period of thought. Needless to say, there are many illuminating remarks and suggestions scattered through it;

and it may serve as a useful jumping-off ground for a student who wants to proceed next to the mastery of current controversies in this rapidly changing sphere of thought and research.

H. J. FLEURE

THE PYRENEES AND CANTABRIAN MOUNTAINS

M. SORRE. **Les Pyrénées.** 216 pp.; maps, diagrs., ills., bibliogr., glossary. (Collection Armand Colin, No. 15.) Librairie Armand Colin, Paris, 1922. 5 frs. 7 x 4½ inches.

F. SCHRADER. **Massif de Gavarnie et du Mont Perdu.** 1:20,000. Henry Barrère, Paris, 1914.

LUDOVIC GAURIER. **Études glaciaires dans les Pyrénées françaises et espagnoles de 1900 à 1909.** With a preface by Charles Rabot. xvi and 363 pp.; map, diagr., ills. Pau, 1921. 9¾ x 6¼ inches.

PEDRO PIDAL AND J. F. ZABALA. **Picos de Europa: Contribución al estudio de las montañas españolas.** 120 pp.; maps, ills., index. Club Alpino Español, Madrid, 1918. 11 x 8 inches.

A. D'A. DE SAINT-SAUD. **Monographie des Picos de Europa (Pyrénées Cantabriques et Asturiennes).** With a Preface by F. Schrader. xiii and 271 pp.; map, diagr., ills., index. Accompanied by portfolio of four maps by L. Maury. Henry Barrère, Paris, 1922. Text 10 x 6½ inches, portfolio 11¼ x 8¼ inches.

M. Sorre's well balanced and picturesquely phrased little regional study of the Pyrenees represents the best traditions of the modern French school of geography. It comprises three parts: the first gives a general view of the Pyrenees as a whole; the second a detailed account of the different regions into which they may be divided; and the third a brief discussion of their natural resources. The volume is a scholarly popularization of a type which the French show true genius in producing.

Although neither as lofty nor as extensive as the Alps, the Pyrenees may nevertheless be regarded as a mountain region of the first order on the basis of other elements than topography. The climate, for instance, though modified by the narrowness of the range and by the equalizing breath of the ocean, reveals such phenomena as the pronounced local inversions of temperature and the well-developed valley breezes associated only with high mountains. The Pyrenees are also sufficiently high and well-defined to mark a climatic frontier between the dry plateaus of northern Spain and the rainy plains of southeastern France. There are likewise striking differences between the moist western valleys on the French side and the warmer, drier pockets of Roussillon and Cerdagne where Mediterranean influences prevail. From the human point of view local climates, soils, and topography are sufficiently varied to have given rise to some of those conditions of life typical only of truly Alpine environments: "ces déplacements périodiques, ce rythme saisonnier de la vie qualifié parfois de nomadisme non sans abus de langage, et l'autonomie des vallées et l'émigration."

The uplifted eastern half of the Pyrenees was maturely eroded during a former cycle of erosion before the uplift took place. It now presents smoothly sweeping slopes into which the streams of the present cycle are vigorously cutting young valleys. To the west the present cycle has progressed far enough to wear away most of the older surfaces, leaving bold and rugged summits. Glacial action has also contributed to the roughening of the topography. The famous Cirque de Gavarnie, at the headwaters of the Gave de Pau, is an impressive amphitheater, scooped out in the past by vastly larger glaciers than those now clinging to its walls. Schrader's

striking map represents graphically the contrast between the cliffs of the cirque and the smooth, mature slopes out of which the cirque has been cut.

Compared with the glaciers of the Alps the existing glaciers of the Pyrenees are insignificant. Altogether they occupy barely more than 25 square kilometers—an area, as M. Charles Rabot explains in his preface to M. Gaurier's book—about equivalent to that of a single Alpine glacier of average size. These glaciers, nevertheless, are important in that they serve as sensitive indices of climatic change. The water supply which they and the melting snows of the mountains give forth in the summer determines to a large extent the agricultural and industrial destinies of the Pyrenean valleys. M. Gaurier's monograph, when complete, will be a detailed study of the glaciers past and present and of the hydrography of the Central Pyrenees. The present volume, devoted to glaciers, lakes, streams, and snowfall of the valleys contributory to the Gave de Pau and to the hydrography of the Gave d'Ossau, is of great value by reason of the wealth of careful and minute observations of which it forms the record.

The Picos de Europa are the highest, wildest crags of the Cantabrian mountains, topographically, at least, the westward continuation of the Pyrenees in northern Spain. Though the loftiest summit does not rise above 2639 meters (8658 feet), the massif is Alpine in the rugged character of its crests and in the presence of snow fields and small glaciers. Sometimes not altogether aptly it has been styled the Dolomites of Spain. The two volumes listed above which deal with these mountains are the work of mountaineering enthusiasts; enthusiasts, however, with pronounced scientific interests, who have incorporated into their books, besides the narratives of ascents, observations of no little value on topography, geology, climate, and people.

Lieutenant Maury's maps of the Picos de Europa, which accompany the Comte de St. Saud's volumes, have been drawn in the spirit of scientific cartography; regions not actually observed are left blank. These maps, together with Schrader's "Gavarnie," are unusually valuable contributions to the documentary material available for the study of the comparative physiography of high mountains.

Travel Notes in Italian Somaliland

Giuseppe Stefanini. **In Somalia: Note e impressioni di viaggio.** 343 pp.; map, ills. Felice Le Monnier, Florence, 1922. 9½ x 6½ inches. 45 lire.

This volume presents a semipopular record of a tour undertaken in 1913 under the auspices of the Government of Italian Somaliland, primarily for a study of its subterranean water sources and to obtain some knowledge of the geology and mineralogy of the colony. The political capital, Mogadishu, founded about 900 A. D., and most flourishing under the M'doffer dynasty (1200–1600), is described at some length with an outline of its history; but its ancient mosques, which would well deserve consideration, are dismissed with tantalizing brevity—a statement which, unfortunately, also holds true for the account of the Mohammedan ruins at Amarr Gegeb, about five kilometers to the southwest. Merka, the agricultural center, and Barava, the chief commercial port—both ancient towns—are likewise described; but the account of Bardera seems, except as a picture of a large Somali village, a little disproportionate, particularly as it is scarcely likely to become of either commercial or industrial importance, while its present political and military value may prove evanescent. Pre-Somali remains, in the form of stone walls, are found at Isha Baidoa, as well as at Uambatti and El Dem; but, unfortunately, no photographs are given, though at least one would have been very welcome to the archeologist.

In view of our somewhat scanty knowledge of the geography of Italian Somaliland, particular interest attaches to the author's study of the Webi Shebeli, which for some 300 kilometers runs closely parallel to the coast, being only 14 kilometers from the sea at Merka, and which, further south, seems to disappear, emptying neither into the ocean nor into another river. It is possible that the marshes where the Shebeli vanishes may possess some outlet which conducts the spate waters of the stream to the Juba, though this remains to be found; and the peculiar course of the river appears to have been caused by the formation of coastal dunes. Similarly the Juba, until 1909, was parallel to the sea and only a few meters distant from it for over three kilometers; but suddenly it broke through the barrier and formed a new mouth, the old one gradually silting up. The entire fourth chapter is devoted to a description of the course of the Juba.

The interesting problem of place names receives further illustration from the toponymy of Somaliland, where the great majority of appellations are derived from animals, vegetation, or soil, as "Red Ox," "High Palm," "Place of Stones."

The ethnology of the Somali is briefly considered. The aboriginal, agricultural negroes were conquered by three waves of pastoral Somali, moving from north to south; and there are likewise mixed breeds, who form distinct tribes. The dwellings are likewise of three types. Note is also made of trees marked with tribal signs whose complete elucidation has not yet been made.

The author is able to give only scanty hopes of important mineral resources in Italian Somaliland. On the other hand, a railway might prove of economic value. Two lines have been suggested: one coastal and the other interior. The former, with its center at Barava, which might at great expense be made a port to serve at all times of year, would not tap the *retroterra*, whose trade is gradually being absorbed by the French to the north and by the British to the south. The second line, in the author's opinion, would be far preferable as tapping the Baidoa (the natural route to the Galla country and to the Shoa); and it should extend to Logh or, better still, to Dolo.

Finally, as regards cartography, it should be observed that existing maps of this region are quite unreliable; but the Istituto Geografico Militare is engaged in making a map on the scale of 1: 50,000.

LOUIS H. GRAY

MISCELLANIES OF TRAVEL MEMORIES

G. N. CURZON. **Tales of Travel.** 405 pp.; map, ills., index. George H. Doran Co., New York, 1923. $7.50. 9½ x 6½ inches.

D. W. FRESHFIELD. **Below the Snow Line.** viii and 270 pp.; maps, index. Constable & Co., Ltd., London, Bombay, Sydney, 1923. 18s. 9 x 6 inches.

Lord Curzon's volume consists of miscellaneous essays on a broad range of topics. Many of these deal with experiences drawn from journeyings on errands of pleasure or diplomacy in nearly all parts of the world. Most absorbing is the account of a visit in 1894 to the Amir of Afghanistan, Abdur Rahman Khan, a medieval despot of a type the Orient occasionally produces even in modern times, a "strange and almost incredible amalgam of the jester and the cynic, the statesman and the savage," in whom "a passion for cruelty was one of his most inveterate instincts." A map accompanied by a proclamation issued by the Amir and used to arouse the patriotism of his subjects is reproduced by Lord Curzon and will well repay examination by those interested in cartographic eccentricities. Other chapters in "Tales of Travel" tell of journeys to Kairwan and to the falls of the Zambesi and discuss the wrestling contests of Japan. Chapters entitled "Pages from a Diary" and

"Humours of Travel" consist of brief vignettes of characteristic, impressive, or amusing episodes. Three essays, on the other hand, are the results of somewhat extended research into matters which made an especial appeal to the author's imagination. These deal with the sounds which many classical writers describe as having issued from one of the Colossi of Egyptian Thebes, with the great waterfalls of the world, and with singing sands. In the chapter on the last-named topic, Lord Curzon summarizes and subjects to criticism various theories that have been propounded in regard to the mysterious sounds produced by accumulations of sand in some places, sounds that have given rise to stories of goblins and evil spirits and in recent times have puzzled more scientific travelers.

Douglas Freshfield's restful volume, "Below the Snow Line," is akin to Lord Curzon's book in that it too is a miscellany of memories of a lifetime of travel. It differs, however, from "Tales of Travel" in one essential respect. Whereas Lord Curzon roams from the witnessing of barbaric ceremonials at Kairwan to the palace of Kabul, from bullfights to reminiscences of Chinese diplomats, from waterfalls to sonorous sands, Mr. Freshfield's interest is concentrated on mountains. His interest in mountains, however, is by no means a narrow one. He does not confine himself, as is too often the case with mountaineers, to the chronicle of adventures among rocks and ice. Indeed Mr. Freshfield is guilty of the heretical statement that "there are times when nothing but rock and snow becomes monotonous." "Below the Snow Line" is a record of wanderings among the foothills and lower ranges of the Alps, among the Apennines and mountains of Corsica, Greece, Algeria, and Japan. "Below the snow line" usually means, as well, "below the upper limit of vegetation" and often "below the upper limit of human enterprise." After all, mountains within these zones, if not as sublime as the mightier summits, are more varied, more individualistic, and generally more interesting from the geographical point of view. Mr. Freshfield always traveled with the curiosity of the scholar and the eye of the poet. There is enough history and natural science in his essays to give them background and substantiality but not too much to weary the "general reader." There is enough skill in the use of words to give color. To quote but one phrase, descriptive of a view in the Apennines at sunset: "Far away southward the snows on the huge bulk of the Majella glowed like a burning coal through the tremulous waves of blue air."

The Geographical Factor in the Early History of Alabama

T. P. Abernethy. **The Formative Period in Alabama, 1815–1828.** 192 pp.; maps, diagrs., ills., bibliogr. *Alabama State Dept. of Archives and History, Hist. and Patriotic Ser., Publ. No. 6.* Montgomery, Ala., 1922.

In the westward advance of our frontier and in the development of the frontier communities into established states geographical conditions played an important part. This fact has been recognized by many of our historians, but none has had a clearer perception of its significance nor has done more to guide students toward the geographical point of view in their historical work than Professor F. J. Turner of Harvard. Dr. Abernethy was one of Professor Turner's students, and the book under review was prepared as a doctoral dissertation under Professor Turner's direction. The volume deals not only with political events in the early history of Alabama but with the settlement of the region and with its agricultural, commercial, and social conditions at a critical time. The geographical factor throughout is given due consideration.

The location and composition of the first settlements in Alabama were determined partly by physiographic circumstances—as revealed more especially in conditions of soils—and partly by the routes from the older communities to the

north and east. The bottom lands of the Tennessee, Alabama, Tombigbee, and Black Warrior Rivers formed the richest agricultural districts of the state and were admirably adapted to the cultivation of cotton. These lands were early occupied by capitalist planters with their numerous slaves. The relatively less productive hilly country was left to farmers with little capital and few slaves. Most of the eastern part of the state was still in the hands of the Creek Indians until 1836. As regards its origins the population was likewise divided. The Tennessee valley and northern counties were peopled mainly by immigrants from Tennessee. The north-central hilly country and the valleys of the Tombigbee and Black Warrior were settled predominantly from the piedmont belt of the Carolinas and Virginia. Planters from Georgia occupied the valley of the Alabama, and Georgian farmers settled in the poorer southeastern counties.

The commercial, social, and political life of the state was influenced to no small degree by the circumstances of its settlement. Owing to the extreme difficulties of communication almost complete commercial separation prevailed between the north and south. Socially, the planters formed a world of their own and had few dealings with the small farmers. Political cleavage soon manifested itself between the latter, mainly of Tennessee origin, and the capitalistic planters who had come in large part from Georgia. Though the state went for Jackson in 1824, it is notable that the largest percentages of votes for the more conservative Adams were polled in the counties where the slave population was the greatest. These and many other points of similar geographical interest are ably discussed by Dr. Abernethy.

County Boundaries of California

Owen C. Coy. **The Genesis of California Counties.** vii and 92 pp.; maps, index. California Historical Survey Commission, Berkeley, 1923. 9 x 6 inches.

Owen C. Coy. **California County Boundaries: A Study of the Division of the State into Counties and the Subsequent Changes in Their Boundaries.** vii and 335 pp.; maps, index. California Historical Survey Commission, Berkeley, 1923. 9 x 6 inches.

At the present time California is divided into 58 counties, more than twice the number (27) first established by an act of the legislature in 1850. Some understanding of the intricate history of the subdivision of the old counties and of the frequent readjustments in their boundaries is essential for all who would undertake studies in the regional geography of the state. Dr. Coy explains in the prefaces to these volumes that in California "statistics are almost invariably given in terms of counties, and the county is the important unit in the state hierarchy. Studies of politics, of production, of population, resources and social developments must make use of county archives. But documents can not be located in the county archives, and can not be historically interpreted, unless it is known under what county jurisdiction they were made and filed and of what territory and social components they treat." The *raison d'être* of the two books under review is to provide a "key to the interpretation of records and figures otherwise difficult of access."

The first-named book was issued as a preliminary to the second, and all the data included in it form Part I of the second. It is a compact historical sketch of the genesis and evolution of California counties illustrated with maps showing the counties at eight different periods. There is also included a general key map of the whole state, by the aid of which one may quickly determine the various counties to which any given part of the state has belonged with the appropriate dates. The second part of "California County Boundaries" consists of a detailed, alphabetically arranged treatment of the changes in the limits of the various counties. A detailed

map is given for each county. The maps are admirably adapted to the presentation of a very complex mass of material, and the text is lucidly written.

Besides being of practical aid to further research, Dr. Coy's work is in itself a valuable contribution toward our understanding of an important phase of the historical and political geography of California. The progress of settlement is reflected in the number and size of the counties. The earliest Spanish and American settlements in California lay in the vicinity of San Francisco Bay and along the coast to the south, in the Sacramento Valley, and in the mining camps of the Sierras north of the Tuolumne River. As shown on the maps of 1850 and 1852 these parts of the state were already at that time divided into numerous counties of relatively small extent. Four large counties, on the other hand, made up the almost unsettled northern and southern extremities and the south-central interior back of the coast range. With the influx of population during the next fifty years and with its dissemination over the entire area of the state, all the larger and many of the smaller original counties were split up, though a fan-shaped group of comparatively small counties radiating from San Francisco Bay back into the Sierras is still apparent on the map for 1922. Imperial, the last of the counties to be organized (1907), was a result of the conversion through irrigation of the Imperial Valley from a desert into a prosperous fruit-raising district.

The vigorous expansion of Californian settlement led in 1852 to a somewhat surprising result, for in that year the legislature passed an act establishing Pautah county entirely outside the boundaries of the state! This act was repealed in 1859. "Many settlers from California and others bound for California had taken up their abode in the valleys of the Truckee, Carson, and Walker Rivers" in what was then the territory of Utah (now part of Nevada). This district was "near the mining region of California and being on the routes of the overland trail had much in common with this state." In 1860 further settlements in the same vicinity led to agitation that took the "form of a joint resolution asking Congress to cede to California" all that part of the present state of Nevada lying west of the 118th Greenwich meridian.

In general the influx of settlers has led to the creation of new counties. One case, however, is recorded where the unstable conditions of a frontier mining community produced the elimination of a county. Klamath, established in 1851, though originally large in territory was progressively reduced in size by annexations to its neighbors "until there was but little left besides rugged mountains whose diminishing wealth formed the main support of its population." As an indirect result of this situation the county was dissolved in 1874, and parts of it were joined to Humboldt and Siskiyou.

Manufactures in the United States

A Graphic Analysis of the Census of Manufactures of the United States, 1849 to 1919. 253 pp.; maps, diagrs. National Industrial Conference Board, New York, 1923. 11 x 9 inches.

This splendidly printed volume, containing one hundred and twenty full page colored charts and an equal number of opposing pages of statistical tables and explanatory text, presents some of the outstanding and essential facts relative to the development and present status of manufacturing in the United States. This vast fund of information is derived from the census reports of the United States, covering the period of its history from 1849 to 1919. Owing to the fact that this body of material has not been utilized to the fullest extent by those most likely to profit from it, the National Industrial Conference Board has undertaken in this volume to analyze and present in a concise, simple, and attractive form the princi-

pal facts relative to industrial conditions in the United States collected by the censuses during the past seventy years.

To the geographer this volume is highly interesting and suggestive. The first one hundred charts and statistical tables relate especially to the economic phases of manufacturing and have to do with such subjects as the number of persons engaged in various industries at different periods, the distribution of the personnel, the value of the products, the major items of expenditure in the different industries, the size of establishments, the character of ownership, the regularity of employment and the prevailing hours of labor, the power and fuel used, and the relation between production, labor, power, and values at different times during the period covered. Occasionally where some of these facts are expressed graphically upon maps of the United States a distinct geographical flavor is imparted to the subject. No explanations are made, however, in the brief space available for text. In most instances an acquaintance with the physical background and other geographical factors in the United States enables the reader to throw much meaning into the charts which otherwise would have only the virtue of presenting vividly some striking facts. Needless to say, much material not usually brought to the geographer's notice thus engages his attention.

The last twenty charts and tables, presenting the status of fifty leading industries in the United States, are especially interesting to one searching for geographic relationships and responses. In each case the extent of the industry is shown by states for the year 1919 and in many cases for the year 1879 as well. It is easy to see at a glance, therefore, the part played by each state and, where the maps for the two years are given, to note also what changes have taken place in the location of the different industries during the past forty years. All of this is of great geographical interest, especially if studied in the light of a clearly understood geographic background. Students of geography would be well repaid for the time spent in examining these charts and in attempting to explain the facts which they so strikingly and beautifully present.

A. K. Lobeck

A Reference Work on World Geography

Martin Vahl and Gudmund Hatt. **Jorden og Menneskelivet: Geografisk Haandbog.** Vol. 1, 572 pp.; maps, diagrs., ills., bibliogr.; Vol. 2, 434 pp.; maps, ills., bibliogr. J. H. Schultz, Copenhagen, 1922, 1923. 10 x 7 inches.

The preparation of this rather exhaustive treatise on general and regional geography was undertaken, according to the author's preface, because of the recognized lack of a scientific reference geography (in Danish). The authors speak of this as a "Haandbog," literally translated as Handbook but much more accurately stated in English as a Reference Geography.

The work when completed is to consist of four volumes with the following contents: Volume 1, General Geography, the Arctic Ocean, and North America; Volume 2, South America, Antarctica, Australia, and the Atlantic, Pacific, and Indian Oceans; Volume 3, Africa and Asia; Volume 4, Europe. There is also to be included a comprehensive catalogue of geographic names.

In Volume 1 the first 118 pages are devoted to a discussion of General Geography. This comprises what American students are beginning to designate "Principles of Geography." A brief summary of essential physical features is presented with no great departure from traditional types of treatment. Most American authors would be inclined to go into more detail than is here done in a work of this size. The summary is followed by a carefully organized discussion of zones of climate and vegetation. The controlling causes of these zones and their resultant relations to human activities are most commendably set forth.

The regional discussion begins boldly with the Arctic Ocean—a procedure certainly not traditional from an American point of view and somewhat startling even from a Danish. Perhaps it is an illustration of the response of a Nordic to his environment, but at any rate it is interesting and not without merit. Then follows a comprehensive treatment of North America, covering nearly 450 pages. Here again the scheme of giving a general introduction and then political divisions in detail is followed. A survey of the structure and geological history of the continent is given, but principal emphasis is placed on climate and vegetation; in fact, natural regions are determined chiefly upon the basis of native vegetation. The general culture map of "old North America" presents the following regions as indicative of the broad culture areas of the continent: Eskimo, Northwest Coast, Northern Forest, Eastern Forest, Prairie, Plateau, California, Pueblo, Mexico and Central America, and the Antilles.

The regional discussions are based on political units and are well correlated with the general principles given in the introductory chapters. The treatment is somewhat encyclopedic in method, and, as is to be expected in a work of this character, is not completely free from error. Yet it gives much emphasis to causal relations and to the geographic influences resulting and so ranks high as a real geographic study.

N. A. BENGTSON

NEW ZEALAND VEGETATION

L. COCKAYNE. **The Vegetation of New Zealand.** xxii and 364 pp.; maps, ills., bibliogr., index. *Die Vegetation der Erde*, Vol. 14, Wilhelm Engelmann, Leipzig; G. E. Stechert & Co., New York, 1921. $5.00. 10 x 7 inches.

L. COCKAYNE. **New Zealand Plants and Their Story.** 2nd edit., rewritten and enlarged. xv and 248 pp.; maps, ills., index. *New Zealand Board of Sci. and Art Manual No. 1.* M. F. Marks, Wellington, 1919. 8½ x 6 inches.

The region treated in "The Vegetation of New Zealand" comprises New Zealand proper and various small outlying islands. New Zealand proper, consisting of two large islands (North and South) and a third smaller one (Stewart), extends approximately north and south from latitude 34° to 47° S. (a distance of about 900 miles), or between latitudes corresponding to those of southern North Carolina and northern Nova Scotia respectively. The climate of the country, no part of which lies more than 100 miles from the sea, is insular, and its truly temperate character is suggested by the fact that tree ferns and many other plants, ordinarily associated with the tropics, range throughout. Both North and South Islands are characterized, in the main, by an extremely rugged topography, the mountains of the Southern Alps rising to elevations of more than 12,000 feet. Precipitation, on the whole, is abundant and evenly distributed through the year. Over most of North Island it exceeds 50 inches annually; along the western coast of South Island it is more than 100 inches; and only in the lee of the Southern Alps does it fall below 30 inches. The outlying islands include the subtropical Kermadecs (latitude 29°–31° S.) and several subantarctic groups, reaching to latitude 54° S.

At the time New Zealand was settled, the plant life of the islands was virtually an unopened book. During the century that has elapsed its flora has become revealed as one of peculiar interest in itself and of surpassing importance in its bearing on various geographical problems. Separated as New Zealand is by more than a thousand miles of open sea from the nearest continental land mass, Australia, it is scarcely surprising to learn that the majority of its plants are endemic—nearly 75 per cent of the vascular species. Somewhat more surprising, in view of its geographic isolation, is the exhibition of well-marked affinities by various elements

in its flora to floras in other parts of the world. In addition to an outstanding element of New Zealand origin, three distinct elements of extraneous origin are present, namely an Australian element, a Malayan element, and a subantarctic element—the latter including many genera and even species common to subantarctic South America. No general discussion of the plant life of New Zealand would be complete that neglected to consider facts such as these, and, from the standpoint of floristic plant geography, they stand out as being of paramount importance. The present work, however, is written primarily from the standpoint of ecological plant geography. It has to do with the environmental relations of New Zealand plants rather than their taxonomic relations. Furthermore, its chief theme is the vegetation of New Zealand, as distinguished from its flora; and individual plants are dealt with chiefly as integral parts of the plant covering as a whole rather than as floristic units. In the words of the author the aim has been "to present as vivid and accurate a picture as possible of the actual vegetation of the country. This surely is the first step in a plant-geographical description of any country. And it is the more necessary in a region, such as New Zealand, possessing a truly virgin vegetation which is rapidly becoming modified, or even destroyed."

The unquestioned success with which the author has achieved this aim may be attributed in no small measure to his admirable method of presentation. In taking up the plant life for various sections of New Zealand, in each case the description of the vegetation itself is prefaced by a description of the more important plants and groups of plants entering into its composition, with reference, more particularly, to their growth forms and other features of ecological significance. Especial emphasis is laid on the "leading physiognomic plants," i. e. those that predominate the landscape and determine the general physiognomy of the plant cover. Four phytogeographical sections are distinguished, namely the seacoast, the lowlands and lower hills, the high mountains, and the outlying islands.

Except for the high mountains and the drier sections of South Island, practically all of New Zealand proper was originally forested. Two ecological types of forest are distinguished, namely hygrophytic rain forest and mesophytic southern-beech (*Nothofagus*) forest, the former being widely distributed throughout the entire region and relatively much more important than the latter, which is confined to the two southern islands. Both types are made up almost wholly of evergreen trees, the practical absence of deciduous species being a noteworthy feature. Characteristic of the rain-forest type are the presence of taxaceous trees, with one or another species frequently predominating; the great abundance of tree ferns and the vast number of ground ferns; the luxuriant growth of lianes and various epiphytic seed plants; the density and storied arrangement of the undergrowth; and the profusion of filmy ferns, mosses, liverworts, and foliaceous lichens. It is essentially the type of forest found elsewhere, for the most part, only in the humid tropics. It exhibits considerable diversity from place to place; but this diversity has to do less with the ecological aspect of the forest than with its taxonomic composition, on the basis of which, chiefly, a number of different rain-forest associations are distinguished. In addition to the forest associations, the lowlands and lower hills support a wide variety of shrubby and herbaceous associations. The seacoast, probably unsurpassed in physical diversity by any area of similar size, presents divers seaweed and other marine associations; associations of gravelly and shingle beaches, of sandy beaches and dunes, of rocky cliffs and promontories; mangrove swamps, coastal thickets, and scrubby forests. The high mountains support a variety of distinctive and, to a large extent, unique types of vegetation. The outlying islands afford many features of fascinating interest, quite distinct from those of New Zealand proper. All of these and other features are described in graphic detail, the work concluding with chapters on the effect of settlement upon the plant covering of New Zealand, the flora of New Zealand and its distribution, and the history of the flora.

The book is written more especially for the scientific reader. The other book by the same author, entitled "New Zealand Plants and Their Story," is now in its second edition. This little book, designed primarily for the non-technical reader, affords a fine example of popularized scientific writing.

G. E. NICHOLS

A STANDARD WORK ON OCEANOGRAPHY

JULES SCHOKALSKY. **Okeanografia [Oceanography].** xiii and iv and 69 and 614 pp.; maps, diagrs., ills., bibliogr., indexes. Petrograd, 1917. 10¼ x 7½ inches.

The oceanographical work of the President of the Russian Geographical Society is too well known in the scientific circles of two hemispheres to need introduction here. What may not be passed over in silence is the abnegation of the man, who in the midst of personal misfortune and the misfortunes of his country can yet maintain his service to science, and this, as much as the value of his works, commands respectful attention.

The present work on oceanography begins with an introductory chapter on the history of the subject and then includes the following subdivisions: (1) distribution of lands and seas (pp. 3–10); (2) level of oceans and seas (pp. 11–17); (3) submarine relief (pp. 17–51); (4) nature of the ocean floors (pp. 52–64); (5) composition and salinity of the sea waters (pp. 67–116); (6) temperature of the sea waters (pp. 117–213); (7) transparency, color, and phosphorescence (pp. 213–225); (8) waves (pp. 226–284); (9) tides (pp. 284–403); (10) currents (pp. 405–564). There is a conclusion of 15 pages.

This glance over the subdivisions of the work and their respective proportions indicates the special interests of the author. Historian of geography as he has shown himself in many international congresses, he has expended much care over the introduction of 69 pages. It is richly and accurately informative. Observations too often forgotten are related, as, for example, the data on the vertical distribution of temperature gathered by the Dupetit-Thouars expedition in the *Venus*, 1836–1839; others, generally unknown, there find place, as the similar determinations carried out by the Russians Krusenstern in the *Nadejda*, 1803–1806, and Kotzebue in the *Rurik*, 1815–1818. Part of the originality of the book, indeed, lies in the light thrown on Russian oceanographical work. It is not merely a matter of *amour propre*. The Russian marine is not to be measured by the modest size of its merchant fleet: it has included in its ranks, besides eminent naval commanders, many distinguished savants; its hydrographic charts and memoirs bear comparison with the best of similar work produced by other nations. It is because he has drawn so largely therefrom that Schokalsky has given us a treatise that happily completes the better-known works of Thoulet and Krümmel. But this proper care in giving a place to his compatriots does not preclude recognition of the debt that oceanography owes to other nations. The American reader will appreciate the reference to Maury, the founder of marine meteorology; to Bache, who in 1844 initiated the study of submarine lithology; and to the U. S. Coast and Geodetic Survey and the Hydrographic Office. Text and figures bear witness to frequent borrowings from these sources.

Besides the figures that one finds in all oceanographical treatises there are many original ones drawn by the author. There is, for instance, the comparative curve of salinity, precipitation, density, temperatures of water and air for the Atlantic Ocean between latitude 60° N. and 60° S. which portrays in a remarkable way the characteristics of the zones of calms, the trade winds, and the westerlies (p. 89). Not less ingenious are the graphs which show on the same meridian in the southern

seas almost complete identity of oceanographical elements in spite of a range of 16° in latitude (from 54° 27′ to 70° 2′ S.) (p. 155). Again we may mention the drift of bottles in the Caspian (p. 536) and in the Japan and Okhotsk Seas (p. 550); the diagram of seiches observed August 25, 1911, at Sevastopol (p. 283); and the tidal map of the French coasts of the Channel (p. 380).

It is to the study of the movements of the seas—waves, tides, and currents—that the author gives most space; less, however, to description, qualitative and quantitative, of these phenomenon than to theoretical explanation. There one sees his mathematical leanings: he is too inclined perhaps to assign very special causes to infinitely complex phenomena; too scrupulous to come to a conclusion after having considered several doctrines; too lengthy sometimes for our taste, not less than 12 pages, for instance, being devoted to Ekman's theory of currents.

A consequence of this disproportion is the excessive brevity of certain parts. Speaking of the depths of the Indian Ocean apropos of the 7000-meters deep off Java, the author does not signify the tectonic interest attaching to this long trough between two arches. Among the many maps in the book it is surprising that one of the variations of temperature of the surface of the seas such as Murray and Schott have given is not included. Why, in speaking of the Humboldt (p. 547) and Benguela (p. 527) currents and the bringing up of cold water from the bottom to the surface, does he not mention, if only in passing, Dinklage and his theory of "Auftriebwasser"? Can one affirm without reserve that the difference of density between the Atlantic and Mediterranean waters provokes a difference of level which results in a surface current from the latter into the former (p. 169)?

The exposition of facts often gains by reference to their immediate consequences. The author notes the effect of the temperatures of the Norwegian Sea during 1901–1905 on the fishing industry and on the growth of the fir tree. When describing the slight salinity of the Gulf of Finland, waters so well known to him, might he not equally well recall that one finds there 67 species of fresh-water fish? Nor does he mention the fact that the warm surface waters of the White Sea in summer support an entirely different fauna from that of the colder waters below, a fact established by the fine work of Knipovitch. The value that such biological details add to the physical facts has recently been shown by R. C. Murphy in his description of the Humboldt Current (*Geogr. Rev.*, Vol. 13, 1923, pp. 81–84).

In short one regrets, and it is the only reproach that can be made, that the author has tended too much to sacrifice description to theory, color to exactitude; that he has not taken the opportunity to vivify the too austere excellence of his admirable work.

P. Camena d'Almeida

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THE APPLICATION OF ACOUSTICS TO SUBMARINE SURVEYING

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It is only seventy years since Maury's chart of the North Atlantic Ocean (1854) gave us the first map of an ocean floor and only fifty years since the *Challenger* expedition sketched out the main contours of the ocean basins. This late development of ocean mapping is due to technical difficulties. A whole volume could be devoted to the history of all the accidents, the labor, the fruitless attempts, the sums expended in reaching a satisfactory method of deep-sea sounding.[1] Even so the direct method of sounding now in general use remains a laborious and expensive process. According to Murray and Hjort the total number of deep-sea soundings, i. e. at depths exceeding 1000 fathoms, numbered barely 6000 (1912), distributed over more than 100,000,000 square miles of area.[2]

The difficulties of direct sounding encouraged resort to indirect methods. Maury has described the earlier efforts. "Attempts to fathom the ocean, both by sound and pressure had been made, but in 'blue water' every trial was only a failure repeated. . . . By exploding heavy charges of powder in the deep sea, when the winds were hushed and all was still, the echo or reverberation from the bottom might, it was held, be heard, and the depth determined from the rate at which sound travels through water."[3] Since the war of 1914, however, various acoustical methods have been developed to the point of giving practical results; and one of them, the "Echo Method," using the sonic depth-finding apparatus, is successful in the deepest waters.[4] Method and apparatus are the result of research work which the U. S. Navy has carried out during the past six years. This work, which was started solely for the purpose of devising methods and means for com-

[1] Julien Thoulet: L'Océanographie, Paris, 1922, p. 16.
[2] Sir John Murray and Johan Hjort: The Depths of the Ocean, London, 1912, pp. 131–132.
[3] M. F. Maury: The Physical Geography of the Sea, New York, 1855, pp. 200–201.
[4] On methods used in shallower waters see H. C. Hayes: Measuring Ocean Depths by Acoustical Methods, *Journ. Franklin Inst.*, Vol. 197, 1924, pp. 323–354.

bating submarine boats, has led to the development of an instrument of great oceanographical and navigational value.

Practical Results

The first practical design of the sonic depth-finding apparatus was installed on the *Ohio* and successfully tested in February, 1922. The following June this apparatus was transferred to the destroyer *Stewart* just previous to her departure for Manila by way of Gibraltar and the Suez Canal. Throughout the run to Manila soundings were taken every twenty minutes and at times as often as every minute. The greatest depth encountered was 3200 fathoms. This ship is still based on Manila and during the past two years has collected a large number of sounding data about the Philippines. The *Stewart* will probably return this year by way of the Pacific, thereby completing a line of soundings around the earth.

As a result of the success of the *Stewart* the destroyers *Hull* and *Corey* were equipped with the depth-sounding apparatus and directly proceeded to survey about 35,000 square miles off the coast of California. This work was accomplished at the rate of about 1000 square miles a day. The results have been assembled on U. S. Hydrographic Office Chart No. 5194. The specific reason for this survey was the unstable character of this portion of the earth's surface.[5] A comparison of the present chart with older charted values show many discrepancies, whether due to errors in the earlier surveys or to earth movements is not known. A resurvey will show the effects of any subsequent crustal disturbance.

Since that time several other ships of the Navy have been equipped, as has also the Coast and Geodetic Survey ship *Guide*. These ships are taking soundings during every cruise, with the result that the Hydrographic Office is receiving an enormous amount of reliable deep-sea sounding data which has already served to clear up several doubtful regions on the navigational charts and which is rapidly leading to an accurate charting of the depth along the main traffic routes. These data have disclosed discrepancies of hundreds and even thousands of fathoms between the actual depth and the old charted values. The discovery of mountain peaks or ridges rising several thousand feet above the surrounding sea floor is not unusual. Such "landmarks" will doubtless prove to be valuable for determining the location and progress of merchant ships that are provided with deep-sea sounding apparatus.

The scientific value of the data that can now be collected with the sonic depth-finding apparatus can scarcely be overestimated. It should furnish valuable information concerning the movements of the earth's crust for the reason that the contour of the sea floor, which has been protected

[5] See the paper "The Continental Shelf off the Coast of California," by A. C. Lawson, *Bull. Natl. Research Council*, No. 44, Vol. 8, 1924.

The submarine contours have also been incorporated on the "Fault Map of California," reviewed in the *Geogr. Rev.*, Vol. 14, 1924, pp. 301–302.

from the processes of erosion, is the direct result of such movements and also for the reason that the most unstable portions of the earth's surface, where movements are so great and violent as to affect areas far beyond their origin, form a part of the sea bottom. It may be expected that a careful study of the form and movements of the sea floor brought about by the earth-warping forces will lead to a better understanding of these forces.

Surveying Data

The data which the surveying ship collects consist of a record of the distance from the ship to the sea bottom along a line perpendicular to the sea bottom, together with the direction of this line with respect to the sea surface. A determination of these factors, which furnish complete data for plotting the profile of the sea bottom over the course traversed, can be made as often as every two or three minutes while the ship steams steadily on her course. Profile charts along parallel courses not too widely separated furnish sufficient data for preparing contour maps or for constructing contour models.

Method

The distance from the surveying ship to the sea bottom along a line perpendicular to the sea bottom is obtained through a determination of the time interval between the transmission of a submarine sound signal from the survey ship and the return of the echo of the signal from the sea bottom. Half of this time interval multiplied by the velocity of sound in sea water gives the distance from the ship to the point of reflection. And since the echo returns along practically the same path that the signal traverses in reaching the reflecting surface, the direction of the echo will be perpendicular to the reflecting surface. The direction of the echo with respect to two horizontal rectangular axes, one parallel with the ship's keel and the other directed athwartship, is determined by the sound receiver installed on the ship. It will be shown that this furnishes data for computing the angle which the echo path makes with the sea surface.

Apparatus

The complete surveying installation of sound apparatus consists of three parts, viz. a submarine sound transmitter, a submarine sound receiver, and a device that serves to determine the time interval between the sending of a sound signal with the transmitter and the return of its echo through the receiver. In literature dealing with the subject the transmitter is sometimes called a submarine oscillator, and the receiver is usually called a hydrophone. The time-measuring device has been called the "sonic depth finder," a name that is entirely misleading. No single one of the devices mentioned can furnish data sufficient for making a depth determination. We prefer to speak of the complete installation as the "sonic depth-finding apparatus." A description of each of the three parts follows.

THE SUBMARINE SOUND TRANSMITTER

The principle of operation of the submarine sound transmitter is identical with that of an ordinary telephone receiver wherein a diaphragm is caused to vibrate through the action of a variable electric current passing through one or more coils of an electromagnet housed in a casing on one side of the diaphragm. Any motion of the diaphragm sets up compression waves in the air, thereby producing sound. The telephone is a sound transmitter.

Owing to the high incompressibility of water a diaphragm exposed to this medium must be subjected to push-and-pull forces of considerable magnitude to cause it to vibrate through even a very small amplitude, and as a result the submarine sound transmitter is a heavy rugged device carrying powerful electromagnets. The diaphragm is a disk of solid steel about twenty inches in diameter and from a half to three-quarters of an inch thick. The coils of the electromagnets are supplied with alternating current from a two-and-a-half kilowatt generator, and the resulting forces on the diaphragm may equal several tons. The pitch of the sound generated by the diaphragm is numerically equal to the frequency of the alternating current supplied. Sounds having a pitch of 550 and of 1100 are employed with about equal success. The alternating current circuit is provided with a key by means of which the transmitter can be used for sending code or other kinds of signals.

THE SUBMARINE SOUND RECEIVER

Several types of submarine sound receivers have been perfected, any one of which is commonly called a hydrophone. The type best suited for our purpose is called the "MV Hydrophone." It will be seen that this receiver can be "focused" toward any direction wherein the operator may care to listen and that this results in intensifying the sound from the desired direction and at the same time weakening the response to sounds from other directions. The principle of operation of this device can be more readily understood by first considering how direction is determined by the unaided ears.

The sense of direction of sounds, the "binaural sense," is largely dependent upon the difference in the time of arrival of the sound at the two ears. If the sound waves stimulate the right ear first, one has the impression that the sound source is located to his right; and, similarly, if the left ear is stimulated first, one gains the impression that the sound source is located to his left. Up to a certain point the angular bearing to the right or left of the sound source is judged to be greater as the interval between the time of arrival at the two ears becomes greater. When this time interval is zero, or in other words when the sound waves strike the two ears simultaneously, the sound source seems to be neither to the right nor left. One may then have the impression that the sound comes from ahead or overhead or behind or in fact from any point in the plane that is a perpendicular bisector of the straight line joining the two ears. A sound that stimulates the two

ears simultaneously is said to be "binaurally centered" and the source of such a sound is said to be located in the "binaural plane." A straight line joining the two sound receptors (in this case the two ears) is commonly called the "binaural base line," and the time interval between the arrival of a sound at the two receptors is called the "binaural interval."

Restating the previous paragraph, we may say that the binaural sense enables us to judge the direction of a sound with respect to the binaural base line and that the definite impression we have of the direction of the sound is a result of the magnitude and sense of the binaural interval. A sound source is judged as lying in the binaural plane when the binaural interval is zero, or in other words when the sound is binaurally centered.

The binaural interval is not much affected by turning the head slightly when the sound is directed parallel with the binaural base line, and as a result such directions cannot be judged with a high degree of accuracy. The change produced in the binaural interval for a slight turn of the head is greatest for sounds directed perpendicular to the binaural base line (for sounds that are binaurally centered), and as a result the direction of such

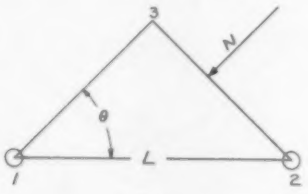

FIG. 1

sounds can be judged with greatest accuracy. The acuteness of the binaural sense for different individuals is surprisingly uniform and is such as to recognize a change in the binaural interval of the order of five millionths of a second.

The relation between the binaural interval and the direction of a sound is shown in Figure 1, wherein numerals (1) and (2) represent the two sound receptors (the ears), the vector (N) represents the direction of propagation of the sound, the line (2–3) represents the direction of the wave front, (L) represents the binaural base line, and (θ) represents the angle the vector (N) makes with (L). The binaural interval (t) is equal to the time required for the sound to travel the distance (3–1). This is equal to the binaural interval multiplied by (V) the velocity of the sound. Expressed as an equation this relation becomes:

$$(1) \quad V.t = L.\cos\theta,$$

$$(2) \quad \theta = \cos^{-1}\frac{V}{L}t = \cos^{-1} K.\, t.$$

Our sense of direction operates in accordance with this equation and has been developed under the particular conditions where (V) is the veloc-

ity of sound in air and (L) is the spacing between the two ears. Our ability to judge the direction of sounds in some medium other than air could not in general be depended upon, for the reason that the constant (K) of this equation would be changed through a change in the velocity of sound. If the ratio of (V) to (L) is kept constant, the ability to judge direction is independent of the medium. In the case of submarine sounds the velocity is nearly five times that in air, and as a result our ears would need to be spaced about five times as far apart if we were to employ them for determining the direction of such sounds. If the binaural constant (K) is made greater or smaller than its normal value, then the angle (θ) is judged to be smaller or greater, respectively, than it actually is.

The normal value of (K) is about 3.0×10^3, and the binaural sense is sufficiently acute to determine (t) to within 5×10^{-5} seconds. It follows

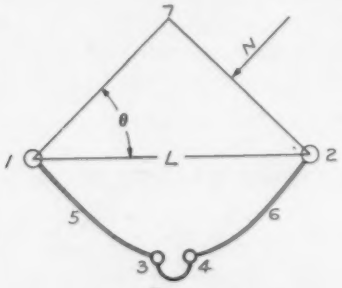

FIG. 2

that for binaurally centered sounds the value of (θ) becomes $\pi/2$ to within a plus or minus error equal to the anticosine of .015, or to within about one degree. This error depends somewhat on the character of the sound, increasing with the purity and pitch, but is well within five degrees for any normal person.

It will now be shown that the error made in judging the direction of a binaurally centered sound can be reduced to a small fraction of a degree. It has been seen that this error ($\Delta\theta$) is represented by

$$(3) \quad \Delta\theta = \cos^{-1}\frac{V.\Delta t}{L}.$$

In the expression ($V.\,\Delta\,t/L$) the factor (V) is fixed since it depends only upon the physical characteristics of the medium, and (Δt) is also fixed since it depends upon the acuteness of the binaural sense. But the factor (L) can be varied to suit our fancy by replacing the ears by two equal sound receptors that are connected, one to each ear respectively, through equal energy-conducting paths. Such an arrangement is shown in Figure 2 wherein numerals (1) and (2) represent the two receptors, (3) and (4) represent the two telephone receivers or other means used to convey the sounds to the two ears, and (5) and (6) represent the two equal energy-conducting paths connecting each receptor with its respective ear.

The sound can be binaurally centered by turning the two receptors so that the base line (L) is normal to the vector (N). The angle (θ) will then be $\pi/2$ to within an angle ($\Delta\theta$) represented equation (3). This error will be inversely proportional to the value of (L). It will be seen that the MV Hydrophone takes advantage of this fact.

Referring again to Figure 2, it will be seen that the sound could be binaurally centered by varying the time of energy transit across paths (5) and (6) as well as by rotating the base line (L). The difference in time of arrival of the sound at the two ears is evidently equal to the time required for sound to travel across the length (7–1). This distance, which may be called (S), is equal to the product of the velocity (V) and the binaural interval (t), or

$$(4) \quad S = V.\, t,$$

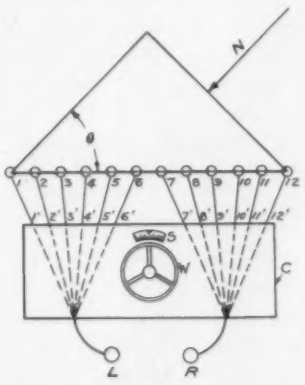

FIG. 3

and the time (t) is equal to the distance (S) divided by the velocity of sound. If the paths (5) and (6) are so designed that the time of energy transit across them can be increased or decreased uniformly and by known amounts, then, if they were adjusted until the time of transit across path (6) is (t) seconds greater than across (5), the sound would reach the two ears simultaneously and would be binaurally centered. Conversely, if the paths are adjusted until the sound is binaurally centered, the difference in time of transit across the two paths gives (t), and this multiplied by (V) determines the length (7–1), which together with the known value of (L) determines (θ), the direction of the sound with respect to (L).

The process of binaurally centering a sound by varying the time of energy transit across the energy-conducting paths connecting the receptors to the ears is called "compensation," and any device for accomplishing this is called a "compensator."

The principle of operation of the MV Hydrophone can now be understood in connection with Figure 3, wherein numerals (1) to (12) inclusive

represent the receptors uniformly spaced along a straight line, numerals (1′) to (12′) represent the energy-conducting paths, the rectangle (*C*) through which all the energy paths pass represents the compensator, and (*R*) and (*L*) represent the telephone receivers or other means for bringing the energy paths to the two ears. It is to be noted that half of the receptors connect with each ear respectively. The figure shows six, but more or less than this number can be employed. The compensator (*C*) is so designed that the response of all the receptors to sound from any direction (*N*) can be made to reach the two receivers (*R*) and (*L*) simultaneously by turning the wheel (*W*) of the compensator, and the scale (*S*) is calibrated to read the direction (θ) for any sound that is brought to a binaural center by turning the compensator handwheel. The intensity of any sound that is binaurally centered is relatively great for the reason that the responses to this sound of all the receptors reach their respective ear terminal in phase while the response to sounds from other directions is weakened through the process of wave interference. This results in weakening the local disturbing sounds caused by propellers, auxiliary machinery, and slapping of waves. The benefit resulting from the use of a multiplicity of receptors is therefore seen to be marked, since it intensifies the sounds desired and at the same time weakens those from other directions.

It is to be noted that the MV Hydrophone, as described, determines only the direction of a sound with respect to the line of receivers. The source might lie anywhere on the surface of a cone having its vertex at the center of the line of receivers, which is the axis of the cone, and making an angle (θ) with the axis. If the direction is determined with respect to a second line of receptors inclined to the first line, then the direction of the source is uniquely determined by the line of intersection of the two cones.

The actual installation carries two lines of receivers so arranged that the direction of any sound can be determined with respect to the ship's keel and with respect to a direction athwartship, and this furnishes complete data for determining the direction uniquely.

The technical details of the MV Hydrophone would be out of place in this paper, which only aims to describe the principle of operation of the depth-sounding apparatus. It may be stated, however, that the device is electrical throughout. Each sound receptor carries a microphone that is stimulated by the submarine sound waves, and within the compensator the electrical circuit of each receptor includes a number of so-called electrical retardation units. The time of electrical transit of each circuit is varied by varying the number of these units included in the circuit. This is accomplished by turning a single handwheel. The electrical output from the receptors is brought to the ears and there transformed to sound by telephone receivers, one of which receives the output from half of the receptors and the other of which receives the output from the other half.

THE SONIC DEPTH FINDER

The sonic depth finder, or time-measuring device, is simply an automatic transmitting key designed to close the transmitter circuit for a short interval at the end of equal periods of time. This causes the transmitter to send out submarine sound signals of the nature of short dashes uniformly spaced with respect to time. The device is also provided with means for continuously varying the time between successive signals through all values included between one-tenth of a second and ten seconds. The time interval between the transmitting of a signal and the return of its echo from a submarine reflecting surface is determined as a function of the time interval between successive signals. It will be seen that this function becomes very simple when the interval between signals is so adjusted that an echo returns to the receiver at the same instant that a signal leaves the transmitter.

The device is provided with a two-way switch whereby the two telephones can be connected to the two output terminals of the compensator, as described and as employed for determining directions, or whereby one telephone receiver only is connected to the output from the compensator and the other is connected inductively to the A. C. circuit that drives the transmitter. The latter arrangement enables the listener to hear each signal in one phone at the instant it is transmitted and to hear its echo in the other phone at the instant it reaches the hydrophone. The simultaneity of arrival of sound at the two ears can be judged with a high degree of accuracy, and as a result the adjustment of the time interval between signals to a value that makes the echo arrive at the same instant a signal is transmitted can be made with extreme definiteness and precision.

Assume the period (p) between signals is such that the echo of a signal returns at the instant the next successive signal is transmitted. Then (t) the time of sound transit to the reflecting surface and back again is equal to the period between signals. Suppose then that the period between signals is made equal to half its former value. Then at the instant a signal leaves the transmitter the echo of the second previous signal will arrive at the receiver. Finally, suppose that the frequency of the signals is made (N) times as great. Then at the instant a signal is transmitted the echo of the Nth previous signal arrives at the hydrophone. It will therefore be seen that the relation between the time of transit (t) and the interval between signals (p) can be expressed by the simple equation,

$$(5) \quad t = N.\, p,$$

where (N) is a whole number. It can be shown that (N) is numerically equal to the number of signals in transit. Its value can be determined by counting the number of signals that are transmitted before an echo is heard or by counting the number of echoes that are heard after the transmitter is stopped. However, we shall see that this procedure is not necessary.

If (S) now represents the distance to the reflecting surface and back and

(V) represents the velocity of sound, then the distance will be equal to the velocity multiplied by the time, or

$$(6) \quad S = V.\, t$$

and

$$(7) \quad H = \tfrac{1}{2}\, V.\, t,$$

where (H) represents the distance to the reflecting surface. Substituting the value of (t) from equation (5) we have

$$(8) \quad H = \tfrac{1}{2}\, V.\, N.\, p,$$

where (p) is the interval between signals and (N) is a whole number to be determined.

The mechanism for varying the value of (p) and for determining its value consists of a phonograph-like disk driven at constant speed together with a small wheel that can be moved out or in radially along the surface of the disk and which is driven through friction contact with the disk. The shaft of the friction wheel carries two cam wheels, one of which has one saw-toothed depression and the other of which carries ten such depressions uniformly spaced about its circumference. Each cam operates a pair of contact points, and by means of a two-way switch either pair can be made to operate the transmitter key through the medium of a relay.

The value of (p) is dependent on the speed of the disk, the radius of the friction wheel, the radius of the circle that the friction wheel scribes on the disk, and the number of teeth carried by the cam that operates the contact points. Let (P) be the constant period of revolution of the disk, (r) the radius of the friction wheel, (R) the radius of the circle that the friction wheel scribes on the disk, and (C) the number of teeth on the cam wheel employed to operate the contact points. The relation between these factors is

$$(9) \quad p = \frac{P.\, r}{C.\, R},$$

and by inserting this value in equation (8) we have

$$(10) \quad H = \tfrac{1}{2}\, \frac{V.\, N.\, P.\, r}{C.\, R},$$

an equation wherein all the factors on the right-hand side are known except (N). The factor (R) will be given by the means provided for moving the friction wheel along the radius of the disk. In practice this is done by means of a micrometer screw which gives the value of (R) to within about two thousandths of an inch.

We are now in a position to discuss the factor (N). Suppose the apparatus is adjusted for simultaneity of echoes and signals. Call the radius of the circle scribed on the disk (R_1). Then suppose the frequency of the signals is increased until the next condition for simultaneity is reached. Call the new value of the radius of contact (R_2). We now have the two relations

$$(11) \quad H = \tfrac{1}{2}\, \frac{V.\, N\, P\, r}{C.\, R_1}$$

$$(12) \quad H = \tfrac{1}{2} \frac{V.\,(N+1)\,P.\,r}{C.\,R_2}.$$

The depth (H) being the same in both equations, it follows that

$$(13) \quad N = \frac{R_1}{R_2 - R_1}.$$

Substituting this value for (N) in equation (11) gives for the sounding equation

$$(14) \quad H = \frac{V.\,P.\,r}{2C\,(R_2 - R_1)},$$

where (V) is the velocity of sound, (P) the period of revolution of the disk, (r) the radius of the friction wheel, (C) the number of teeth on the cam, and ($R_2 - R_1$) the distance along the radius of the disk that the friction wheel is moved in passing from one condition of simultaneity of arrival of signals and echoes at the two phones to the next in order.

It will be noticed that the depth formula holds for all values of (R_1) and will therefore hold for the value zero. This means that if the adjustment for simultaneity is made by moving the friction wheel out from the center of the disk to the first position that gives this condition, then (R_1) is zero and the formula simplifies to

$$(15) \quad H = \frac{V.\,P.\,r}{2.\,C.\,R}.$$

The practical apparatus is designed to make (P) equal to ten seconds, (r) equal to unity, and takes 4800 feet per second as the velocity of sound. It has already been stated that (C) may be made either one or ten depending upon which cam is employed. Inserting these values in equation (15) gives for the working formula

$$(16) \quad H \text{ (feet)} = \frac{24{,}000}{C.\,R},$$

or

$$(17) \quad H \text{ (fathoms)} = \frac{4000}{C.\,R}.$$

The sonic depth finder determines all the factors on the right-hand side of equation (15) to within from one per cent to two tenths of one per cent except the factor (V) which is not dependent upon this device. The velocity of sound in sea water under various conditions of temperature, pressure, and salinity is known with a fair degree of accuracy; but the correction for these three factors cannot always be accurately made for the reason that the temperature, pressure, and salinity over the whole sound path are not known.

Sixteen hundred yards per second has proved to be a good average value for the velocity; but, if a high degree of accuracy is required, the results obtained by using this value must be multiplied by a correction factor which will scarcely ever differ from unity by more than one per cent.

The value of the correction factor will depend upon the temperature, pressure, and salinity and will, therefore, doubtless hold fairly constant over large areas. The U. S. Coast and Geodetic Survey ship *Guide* is making an extended comparison of depths obtained by the deep-sea sounding machine and the sonic depth-finding apparatus, and this work is throwing considerable light on the correction factor. It may be stated, however, that for surveying purposes differences or changes in depth are of more importance than the actual depth, and such information is given with sufficient accuracy by the uncorrected data.

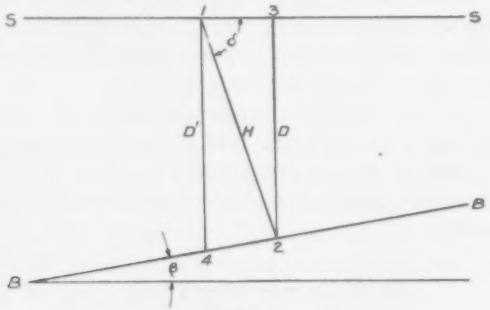

FIG. 4

SUBMARINE SURVEYING

The sonic depth-finding apparatus enables a ship to take a sounding as often as desired while steaming steadily along her course. The minimum depth that can be determined by the sonic depth finder in its present form is 40 fathoms. The maximum is not known. The *Guide* has recently taken soundings to depths of over 5000 fathoms, and her personnel believe the installation is capable of sounding the greatest ocean depths.

The minimum depth is not limited to 40 fathoms and is being made 10 fathoms in a redesign of the apparatus. So far as its use in the Navy is concerned there is no need for reducing the minimum depth below 10 or even 40 fathoms for the reason that shallow soundings can be taken by measuring with the MV Hydrophone the angle which oscillator signals or propeller sounds reflected from the sea bottom make with the ship's keel.[6] There is no inherent reason why the apparatus cannot be designed to take soundings as shoal as 10 fathoms and probably less.

The sounding data given by the sonic depth-finding apparatus consist of the distance to the reflecting surface along a direction perpendicular

[6] H. C. Hayes: U. S. Navy MV Type of Hydrophone as an Aid and Safeguard to Navigation, *Proc. Amer. Philos. Soc.*, Vol. 59, 1920, pp. 371–404.

to this surface, together with the direction of the echo with respect to the ship's keel and also with respect to a direction athwartship. The keel and athwartship directions are perpendicular to each other and define a horizontal plane.

Obviously the distance factor, which has been designated as (H), is not the depth except when the sea bottom is horizontal. The depth underneath the ship will be greater than (H), and the depth above the reflecting surface will be less than (H), wherever the sea bottom is not horizontal. These relations are shown in Figure 4, wherein $(S\text{-}S)$ and $(B\text{-}B)$ represent the sea surface and the sea bottom, and numerals (1), (2), (3), and (4) represent respectively the location of the ship, the point of reflection, the point on the surface vertically above the point of reflection, and the point on the sea bottom vertically beneath the ship. The angle of dip which the direction (H) makes with the surface is represented by (δ), and the slope of the sea bottom is represented by (β). The angle of dip and the slope of the sea bottom are complementary angles, and therefore a measurement of (δ) serves to determine the slope of the sea bottom.

The hydrophone does not measure the angle (δ) directly but gives the angles (ϕ) and (θ) which the direction of the echo makes with the keel and athwartship directions respectively. The angle (δ), which the direction of the echo makes with the sea surface and (α), the angle which this direction makes with the keel in an azimuth plane, bear the following relations to (ϕ) and (θ):

$$(18) \quad \cos\delta = (\cos^2\theta + \cos^2\phi)^{\frac{1}{2}}$$

$$(19) \quad \tan\alpha = \cos\theta/\cos\phi.$$

From these relations it is possible to determine the value of (D), as shown in Figure 4 through the relation

$$(20) \quad D = H.\sin\delta,$$

and (D^1), the depth beneath the ship, will be given by the relation

$$(21) \quad D^1 = H/\sin\delta,$$

providing the slope over the region including points (2) and (4) is constant.

Assuming a slope of 30 degrees for the sea bottom (a value that is doubtless abnormal) and a depth of 6000 fathoms, the horizontal distance between points (1) and (3) of Figure 4 would be three miles. Under the best conditions a ship cannot know its position at sea to within a radius of two miles. The value of (H) can be shown to be very nearly equal to one half the sum of (D) and (D^1) for slopes less than 30 degrees, and as a result (H) represents the true depth at a point about midway between points (1) and (3) of Figure 4. Therefore (H) always represents the true depth at some point within the area of uncertainty as regards the location of the ship when the location is determined by solar checks. From these considerations it appears that the value (H) serves as well for the preparation of charts and for purposes of navigation as does the more accurate value (D) unless some means is devised for more accurately locating a ship at sea.

Since the determination of (H) does not involve a knowledge of the direction of the echo the question naturally arises, Why not employ a much simpler receiver than the MV Hydrophone? The answer is that very good sounding data can be taken with the simplest kind of submarine sound receiver consisting of a single receptor of the microphone type. However, even though a ship does not know its actual position on the chart to within two miles, it does know its progress from hour to hour with sufficient accuracy to warrant all possible corrections of the sounding data for the purpose of developing or of identifying the profile of the sea bottom along the course traversed. Moreover, for many purposes the value of a profile is greatest when it defines the intersection of a plane that is perpendicular to the sea floor. The MV Hydrophone enables the navigator to direct his course so that it will define such profiles. If the angle (α) is zero, the point of reflection lies in a vertical plane that includes the path of the ship, and this plane is perpendicular to the sea bottom. From equation (19) it will be seen that when (α) is zero (θ) is ninety degrees. Under such conditions $\cos \theta$ equals zero, and the angle (δ) becomes equal to (ϕ). If, therefore, the course of the surveying ship is directed so that (θ) equals $(\pi/2)$, as can be done if the MV Hydrophone is used for the receiver, the profile of the course has a definite meaning, and the computations relating to the sounding data are greatly simplified; for then the complement of the angle (ϕ) gives directly the slope of the sea floor at the point of reflection.

There is one more reason, already mentioned, why it is desirable to use the MV Hydrophone, namely, that through its focusing power the intensity of its response to the echoes is strengthened while at the same time its response to the numerous local disturbing noises is weakened.